PROCEEDINGS

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XXXV.—*Description of an Apparatus to illustrate the Production of Work by Diffusion.* By C. J. WOODWARD, *B.Sc.**

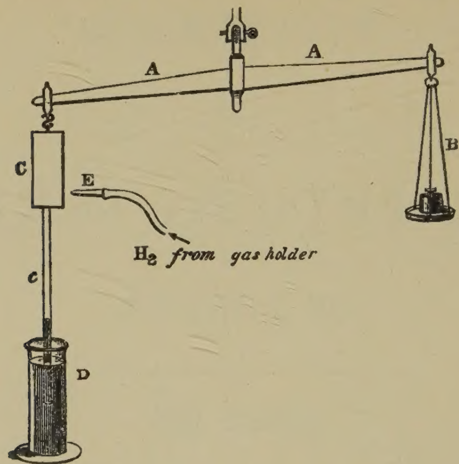
DIFFUSION, as a source of energy, is usually shown in the lecture-room by bringing a jar of hydrogen over a porous vessel fitted up with a glass tube dipping into water. Hydrogen, by inward diffusion, enters the jar; the internal pressure thus produced forces the water down, and a stream of bubbles escapes from the tube. On removing now the jar of hydrogen, outward diffusion of the hydrogen takes place, a minus pressure is produced in the porous vessel, and the water is lifted.

The apparatus I am about to describe is an adaptation of this experiment to the production of an oscillatory movement of a beam from alternate inward and outward diffusion of hydrogen.

The apparatus is represented in the annexed figure. A A is a scale-beam about 3 feet long, carrying at one end a scale-pan and counterpoise, B, and at the other the porous jar, C, fitted with a cork, and a glass tube *c* which dips into a gas-jar, D, containing water or methylated spirit. Three or four glass jets, of which one is shown at E, are supported in a horizontal position, and the opening of each jet is placed as near as possible to the porous vessel without touching it during the oscil-

* Read May 12, 1883.

lations of the beam. These jets are connected by means of a flexible tube with a gas-holder containing hydrogen; the bell of



the holder being loaded so as to force the hydrogen in a gentle stream against the sides of the porous vessel. The best position for the jets is found by trial; but usually I place them a little below the middle of the porous jar when the beam is horizontal. The action of the apparatus is simple. On turning on the hydrogen, inward diffusion takes place, producing plus pressure within the jar; this pressure is resisted equally in all directions but the vertical, and in this direction, owing to the little friction of the water, movement takes place, and the jar rises. When the jar has risen above the jets, inward diffusion diminishes, or perhaps ceases, while outward diffusion of the hydrogen commences; a minus pressure is thus produced in the porous vessel, and the external pressure of the air causes it to descend. This descent brings the jar again opposite the jets, when the series of movements again begins.

The work done with this arrangement is very small, and falls far short of the theoretical value*. For the best effect

* "The work that may be done during the mixing of the volumes v_1 and v_2 of two different gases is the same as that which would be gained during the expansion of the first gas from volume v_1 to volume v_1+v_2, together with the work gained during the expansion of the second gas from v_2 to v_1+v_2, the expansion being supposed to be made into vacuum." See a paper by Lord Rayleigh in the Phil. Mag. [4] xlix. p. 311.

the jar should be surrounded by hydrogen for inward diffusion to take place, and subsequently the connexion with the hydrogen should be completely cut off and air take its place. I have tried to devise some water-seal arrangement by which the flow of hydrogen could be turned off and on at the right moments by the movement of the beam; but have not succeeded, as the friction thus introduced would be more than the movement of the beam could overcome. In the arrangement exhibited there is a considerable waste of energy due to the imperfect cut-off of the hydrogen, even when the flow of gas has been regulated so as to obtain the maximum effect.

XXXVI. *Experiments on the Velocity of Sound in Air.* *By* D. J. Blaikley*.

The method of experiment which I venture to bring before you this afternoon is the outcome of various attempts made by me to determine with greater accuracy than had hitherto been done the velocity of sound in small tubes, such as are used for musical instruments; in addition to which practical purpose the idea presented itself to my mind that, if a series of tubes were taken, having their diameters in a definite ratio, the observed results might by calculation be extended so as to include a value for a tube of infinite diameter, that is for free air. Some of the results were brought before the Musical Association in June last; but the experiments have since been repeated with greater accuracy.

It will not be necessary to take up your time by referring to more than a few of the many determinations that have been made. A useful summary was given by Mr. Bosanquet in the 'Philosophical Magazine' for April 1877; but we may note that only those observations in which corrections both for temperature and for moisture have been made can be considered at all accurate.

Such corrections being made, there remained at the time of Regnault's great series of experiments† considerable differences in the results arrived at by different observers, partly due,

* Read November 10, 1883.

† *Mémoires de l'Académie des Sciences*, tome xxxvii.

doubtless, to errors of observation and partly to an assumption of the absolute correctness of Laplace's formula, the theory in the application of which is that the excess of pressure in the wave above the barometric pressure of the air is infinitely small.

Experiments on the velocity of sound may be classed as open-air experiments and laboratory experiments; and I venture to think that the latter offer advantages which cannot be enjoyed in open-air work. The usual method in the open air has been for an observer at a distance from a gun to note the time which elapses between the flash and the hearing of the report; but even when the actual record of the time is aided by electrical or other apparatus, some difficulties and sources of error remain. For instance, the accurate registration of temperature and moisture is difficult, especially when the sound-wave passes at various heights above the earth's surface, as is the case when the experiment is carried out on two hills separated by a valley.

Many of these gun-fire determinations were critically examined by Le Roux*, and an estimated correction made for errors in temperature, the readings having been in all probability too high for air some metres above the ground.

Midway in character between open-air and laboratory experiments stand those of Regnault, carried out in gas- and water-mains; one of his reasons for choosing this method being the facility afforded by these tubes for the accurate observation of temperature and moisture. Passing by his work for the moment, we may note the laboratory method employed by Kundt, and also Le Roux's method, the latter giving 330·7 metres at 0° C. Kundt's method consists in its best form in the use of two glass tubes connected by a smaller tube or rod of glass, wood, or metal, this connecting-rod being clamped in certain positions to establish nodes, and its free vibrating ends being fitted with pistons working in the large tubes. The waves are excited by friction in the vibrating rod and transmitted therefrom to the air or other gas in the tubes, and the successive half-wave lengths are registered by the positions assumed by lycopodium dust during the vibration. By using tubes of different diameters he obtained the results

* *Ann. de Chimie*, ser. 4, tom. xii. Nov. 1867.

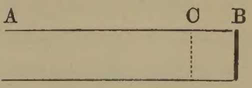
shown in Table I., and came to the conclusion that the velocity observed in his largest tube was not appreciably different from the velocity in free air. He appears, however, to have experienced some difficulty in the determination of pitch, owing to the evanescent character of the sound. The intensity also was not registered. The method is beautifully adapted for comparative rather than for absolute results.

TABLE I.

Velocity of Sound in Tubes, in metres per second, at 0° C. (Kundt.)

Diameter of tube. millim.	Velocity. metre.	Difference. metre.
55	332·80	
		·07
26	332·73	
		2·26
13	329·47	
		6·47
6·5	323·00	
		7·58
3·5	305·42	

Le Roux's method consisted in employing a U-shaped tube, 0·07 metre (70 millim.) diameter, closed by a membrane at each end. One membrane was tapped with a small beater, and the time occupied by the resulting wave in travelling between the two membranes, as indicated by the disturbance of the second one, was registered. It appears to me, however, that the employment of membranes may introduce a source of error in this way:—Let A B be a tube closed by a rigid material at one end, and of a length to give the maximum resonance to a quarter-wave. Now, instead of the rigid end, let the tube be closed by a membrane: this will require to be in the position C, *i. e.* nearer to A than B is, the exact position depending upon the tension of the membrane. In Le Roux's experiments, unless the two membranes were of exactly the same tension, a source of error would be introduced.



We may now turn to Regnault's experiments, a summary of which is here given.

TABLE II.

Velocity of Sound in Tubes, in metres per second, at 0° C.
(Regnault.)

Diameter of tube. millim.	Velocity (mean). metres.	Velocity (limiting). metres.
1100	330·5	330·3
300	330·3	329·25
108	327·52	324·25
Free air.	330·71	330·60

The one point which appears to me to be open to question is whether the rate of diminution of velocity is so great as his work appears to prove; for if this rate of diminution is extended until we reach tubes of the size used in musical instruments, we should have a velocity much less than experiments show to exist in such tubes (compare with Kundt). Probably the want of perfect smoothness in Regnault's tubes may account for some of the difference; but I think that it is doubtful whether the influence of the membranes closing his tubes was thoroughly allowed for, and feel that the question is still an open one.

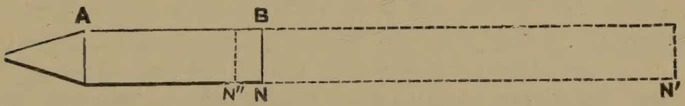
It has long appeared to me that useful results might be obtained by making use of tubes giving musical notes, as the pitch of a steadily sounding note can be readily determined within a remarkable degree of accuracy, and there should be no difficulty in determining the temperature within half a degree Fahr., which is equivalent to 6 inches in the velocity. (Experiment—Resonance of closed tube to fork of 512 vibrations, the length of the tube being modified during the experiment to show both the maximum and constrained or imperfect resonance.) (See paper in Phil. Mag. for May 1879.)

Modifying this experiment by sounding the tube with an organ-pipe mouth, the disturbing influence of the contraction of area at the lip comes into play in addition to the correction for the open end; so that, although the value of the latter is pretty accurately known, no measurement of velocity based merely upon the length of a pipe is at all reliable. By adding, however, a half-wave or wave-length to a stopped pipe, maintaining the original pitch, and measuring this added length, I hoped to be able to get reliable results. The observations,

though agreeing very well indeed so long as the pressure remained constant, did not agree in their different series when taken under very slight differences of pressure, much less than would cause sensible variation through change of intensity, according to Regnault's determinations.

To properly understand the causes of these variations, it will be necessary to examine some of the results of imperfect or constrained resonance, and consider the separate and conjoined influences of (1) the blast, air-reed, or inducing current; (2) the prime tone of the resonating air-column; and (3) the higher or partial tones sounding with the prime; the pitch of the resultant note, or alternating induced current, depending upon the values of these three forces, which have a power of mutual influence within certain limits. The subject presents itself to my mind in the following way :—

In the figure, let the blast from A cause the quarter-wave length of pipe AB to speak a note of a certain pitch, say 105 vibrations, and let BC be the half wave-length of pipe added to AB ; the three-quarter wave-length AC being tuned to



speak the same note as AB. Assuming values in four typical cases, we obtain the following results (p. 324), in working out which arithmetical means instead of mean proportionals have been taken for the sake of numerical simplicity, although perhaps the latter would be more correct.

In Cases 1 and 2 the length NN′ is the true length of a half-wave of 105 vibrations. In (1) the position of N (the node) would remain unchanged on the addition of the half-wave ; but in (2) the three-quarter wave would be of $106\frac{2}{3}$, and N would change its position to N″: this, however, would introduce no error in the result, for $3(106\frac{2}{3})-110=2\times105$, the length for half-wave as determined by the positions of N and N′.

In these two cases it is assumed that the first quarter-wave has equal constraining-power with the added quarters ; but this is not strictly correct for cylindrical organ-pipes, in which the first quarter-wave is shortened and the mass in vibration

	Uncon-strained Pitch.	Difference.	Constrain-ing power or stability.	Difference × Power.	Values of Compo-nents.	No. of Com-ponents.	Pitch of note heard.
CASE 1.—Blast and air-column of same pitch.							
Blast from A	105	....	1	....	105		
Quarter-wave, AB	105	....	1	....	105	÷ 2	= 105
Add half-wave, BC	105	....	1	....	210 210	÷ 4	= 105
CASE 2.—Blast and air-column of different pitches.							
Blast	100	....	1	....	100		
Quarter-wave	110	10	× 1	= 10	110	÷ 2	= 105
(*a*) Add half-wave, BC........	105	5	× 1	= 5	210 210	÷ 4	= 105
Or, Blast	100	....	1	....	100		
(*b*) Three-quarter-wave............................	$106\frac{2}{3}$	$6\frac{2}{3}$	× 1	= $6\frac{2}{3}$	320	÷ 4	= 105
CASE 3.—Blast and air-column of different pitches.							
Blast	100	....	1	....	100		
Quarter-wave	115	15	× $\frac{2}{3}$	= 10	110	÷ 2	= 105
With added half-wave.							
Blast	100	....	1	....	100		
Quarter-wave	$107\frac{1}{2}$	$7\frac{1}{2}$	× $\frac{2}{3}$	= 5	105		
Half-wave..	$107\frac{1}{2}$	$7\frac{1}{2}$	× 1	= $7\frac{1}{2}$	215	÷ 4	= 105
CASE 4.—(Case 2 modified by presence of 12th of prime or 3rd partial.)							
(*a*) Blast	100	....	1	....	100		
Quarter-wave (prime)........................	105	....	1	....	105		
„ „ (3rd partial)...................	$\frac{330}{3}$	....	1	....	110	÷ 3	= 105
(*b*) Blast	100	....	1	... .	100		
Quarter-wave (prime)	105	....	1	......	105	÷ 3	= $103\frac{1}{3}$
„ „ (3rd partial)...................	330 [illegible]	10	× [illegible]	= 5	105		

reduced, through the contraction of the opening at the speaking end. The tendency of this would be to influence the results as shown by Case 3, where the first quarter-wave is assumed to have a mass of $\frac{2}{3}$ instead of unity, and in which the measured length would be represented by $3(107\frac{1}{2})-115 = 207\frac{1}{2}$, whereas it should be $2 \times 105 = 210$.

In Case 4 (*a*), suppose the point N to have been determined for the pitch as heard, 105, with a quarter wave-length of tube. A half-wave is added, and tuned to the original pitch, $= 105$, and NN′ is taken as its measure of length. This is correct if the relative strength of the partials remains the same; but if a modification such as (*b*) takes place, the third partial falling to half-strength, the position of N as observed would no longer be correct for a pitch of 105 but only for a pitch of $103\frac{1}{3}$. A further complication would arise in this case, through the introduction of the point considered in Case 3.

To eliminate these sources of error, one of two things must be attained: we must either deal with pure tones or be careful to have resonating pipes of such form as to have their various proper tones strictly in accord with the harmonic series, and not merely approximately as is the case with organ-pipes; and in either case be careful that the blast is of exactly the power to give the desired note without constraint.

The tubes with which I experimented were of four diameters—·45, ·75, 1·25, and 2·08 inches respectively (11·7, 19·5, 32·5, and 54·1 millim.). After detecting the possible sources of error which have just been described, and trying a few modifications of the ordinary organ-pipe, the speaking ends or first quarter-wave lengths of the tubes were modified in form from cylindrical to pear-shaped, approximating to the shape of Helmholtz's resonators, and by this means a pure tone was obtained. The blast was obtained from a fan, the wind from which passed through a regulating bellows with automatic-valve action, and it was found that great care was necessary on this point. The pressure in the bellows was 2·5 inches of water, and in the speaking mouth in every case very small.

The temperature was observed by means of a thermometer entering the tube, so that the actual temperature during vibration might be recorded. The wet-bulb temperature and barometric pressure were also taken for moisture correc-

tion. The pitch was taken from a carefully tested Koenig fork of 256 vibrations, and the tubes were set to give a beating rate of about 4 per second, the lengths being read by a micrometer and standard rods. All the notes were exceedingly feeble, the pressure in the mouth being less than $\frac{1}{10}$ inch of water, much under the lowest which Regnault found to influence the velocity.

The results are given in the following Table:—

TABLE III.

Velocity of Sound in dry air, at 0° C., in tubes.

Diameter of tube	11·7 millim.	19·5 millim.	32·5 millim.	54·1 millim.
		327·09	328·72	329·90
		327·14	328·74	329·82
		326·98	328·78	329·84
		326·70	328·72	329·70
		327·09	328·72	329·95
		326·69	328·89	329·80
		326·99	328·76	329·53
		326·79	328·84	329·56
		326·70	328·84	329·65
		326·85	328·83	329·48
Means	324·56	326·90	328·78	329·72
Differences ...	2·34	1·88	0·9 4	

I found it very difficult to get observations with the tube of 11·7 millim. diameter. Very many trials were made; and although the best single observation gave 324·78, I have reason to think that the mean value 324·56 is too high. I hope yet to verify it, and also to continue experiments with a tube 90·2 millim. diameter.

There is one point connected with the velocity of sound which appears to require elucidation, and that is, the modification it may undergo near its point of origin; for the waves which affect us as sound are usually not plane-waves, but emanate from an origin which more or less nearly approaches a point—this point being the centre of a system of spherical waves.

We may refer to the vibration in conical tubes as bearing upon this point. A complete cone, speaking its lowest note, with its apex or closed end for the position of the node, is of twice the length of a closed cylindrical tube of the same pitch,

and has the same succession of harmonics as the open cylindrical tube (see Phil. Mag. August 1878). This property is independent of the proportion of base to height in the cone; and if we assume the base of the cone to be a portion of a spherical surface described from the apex, we may continually increase the conical angle until the cone becomes a sphere. Now, if we consider the effect of this principle and apply it to divergent waves, it will be found that such waves cannot have exactly the same velocity for all pitches, but that the lower the pitch the greater will be the velocity, owing to the difference of velocity between the first and succeeding quarter-wave lengths. To take a numerical example, we may choose two wave-lengths of 32 feet and 8 feet respectively:—

	Quarter-wave lengths.		Excess in
	Cylinder.	Cone.	Cone.
32-ft. wave . . .	8 ft.	16 ft.	8 ft.
8-ft. wave . . .	2 ft.	4 ft.	2 ft.
	Difference		6 ft.

Or, if we assume a velocity in free air (away from origin of vibrations) of 1120 feet per second, we shall have:—

Velocity of sound-wave of any pitch, not including first quarter-wave	1120 ft.
Velocity of 8-ft. wave, or wave of 140 vibrations measured from apex of cone, 1120 + 2	1122 ft.
Velocity of 32-ft. wave, or wave of 35 vibrations measured from apex of cone, 1120 + 8	1128 ft.

We thus find that waves near their origin are not of normal length.

In gun-fire experiments the pitch of the explosion is not known, and there may therefore be a variation in the recorded velocities which is due simply to an effect of conical or spherical divergence. If, in addition to the corrections made by Le Roux for temperature, some of the gun-fire experiments were submitted to a correction of this nature, the discrepancies would probably be much reduced.

XXXVII. *On the Purification of Mercury by Distillation* in vacuo. *By* J. W. Clark, *Demonstrator of Physics in University College, Liverpool.*

[Plate XIV.]

The usual processes for the purification of considerable quantities of mercury may be roughly classed as (i.) chemical (*e. g.* treatment with dilute $NO_2(HO)$, $CrO_2(HO)_2$, Fe_2Cl_6, $SO_2(HO)_2$, and $SO_2(HgO_2)$, &c.); (ii.) mechanical (*e. g.* shaking, filtering through wash-leather, &c.); and (iii.) distillation. The last-named process may be conducted either *in vacuo* or under the ordinary pressure.

Of these processes distillation *in vacuo* is in all respects the simplest and most satisfactory. Preparatory to distillation the mercury may be advantageously filtered through a writing-paper cone with a very small orifice at the apex; and when considerable quantities of lead or zinc are present, the distillation *in vacuo* may be hastened by their previous removal by one of the usual chemical methods. It is stated that the presence of $\frac{1}{10000}$ part of lead reduces the amount of mercury distilled in a given time from 67 to 55*. Gold, iridium, silver, copper, tin, nickel, cadmium, and arsenic do not influence the rate of distillation†.

The distillation of mercury under the ordinary pressure is too inconvenient a process to be ordinarily used in laboratories; not so, however, at a temperature of 180°–200° C. *in vacuo.* The first apparatus for this purpose was described by Weinhold‡, and since then Weber§ and A. W. Wright‖ have described other forms. The form shown in section in fig. 1 (Plate XIV.) differs from all the preceding chiefly in being supplied with the mercury to be distilled from a movable reservoir (in the form of a *constant level regulator*, fig. 2), the raising of which fills the distiller with mercury, which thus renders a Sprengel-pump unnecessary to set it in action. It is hoped moreover that its simplicity and efficiency and the ease with which it can be made may render its description useful.

* Gmelin-Kraut, *Hdb. der Chemie*, Bd. iii. Abth. i. S. 740, 6te Aufl.; Millon, *Ann. Chim. Phys.* [3] xviii. p. 337.

† Gmelin-Kraut, *loc. cit.*

‡ *Progr. d. k. Gewerbsch. zu Chemnitz. Rep. für Physik*, Bd. xv. S. 1.

§ *Ibid.* Bd. xv. S. 52.

‖ Chem. News, 1881, p. 311.

The distiller consists of a lead-glass tube, *a b* (fig. 1), 36 inches long, and about $\frac{3}{8}$ of an inch in internal diameter. A bulb of about two inches diameter is blown two inches from its closed upper end. The lower end passes air-tight through a well-secured india-rubber cork which closes the top of the cistern *d c*, and terminates at *b* a little below the tube *f*. The cistern (*d c*) is made from a piece of glass tube 1 inch in diameter and from 8 to 12 inches long, with two short pieces of quill-tubing, *e* and *f*, sealed into it. The lower end is also securely closed with a cork through which passes a piece of ordinary Sprengel-tube, *i*, 36 inches long, with a piece of quill-tubing, *h*, about 24 inches in length, fused onto the upper end. The top of this tube is nearly in contact with *a*. The internal diameter of the Sprengel-tube should not much exceed 1 millim., and the bend at its lower end is best when not much more than one inch in radius. Instead of india-rubber corks, ordinary corks soaked in melted paraffin or covered with sealing-wax may be used, but the apparatus then loses in flexibility.

The base of the stand consists of a wooden tray, C D, from which rises a stout board, D E, carrying a shelf, A E, perforated in the centre with a hole of sufficient size to allow the glass bulb to pass through it. In the Physical Laboratory of University College the board D E which carries the distiller is fixed to the wall over the mercury table. This renders the tray C D unnecessary. A large cork, F, is bored with a hole of rather less diameter than the tube *a b*, and the cork is cut in halves. By placing the tube in the position shown in the figure and twisting a piece of copper wire round the periphery of the halves of the cork, the tube is firmly supported on the shelf. The cistern is secured by string which passes through holes in the projecting piece of wood, B. A block of wood may be placed as a support for the end of the tube *i*. A tin cylinder, slightly notched round the top and covered with a flat tin plate, keeps the bulb surrounded with hot air, whilst a mica window at the side allows the height of the mercury in the bulb to be easily seen. The pipe of the brass ring-burner passes through a hole in the tin case. The diameter of the ring is about half an inch greater than that of the glass bulb, and on the inner side it has a *large number of very small holes.*

The constant-level reservoir (fig. 2) is made from a large bottle provided with a tubulure at the side. Into this passes (through a cork if the tubulure be sufficiently wide—if not, cemented in with sealing-wax) a glass tube, K, about 3 inches in length and $\frac{1}{2}$ inch in diameter. Its outer end is closed, and into the upper and under sides are sealed two pieces of quill-tubing, l and j. The top of the upper one is open, but the lower (j) is connected with the cistern of the distiller by a narrow piece of india-rubber tubing, $m\,m$, about $3\frac{1}{2}$ feet long, enclosed in a canvas tube. By means of an india-rubber (or paraffined) cork the thistle-funnel and small glass stopcock are fitted *air-tight* into the neck of the bottle*. Thus fitted, the reservoir is placed on an ordinary adjustable table-stand on the shelf H (fig. 1). To set the distiller in action, open the stopcock, S, of the reservoir and pour some of the mercury to be distilled through the thistle-funnel, t, into the reservoir, and with a short piece of india-rubber tubing and glass rod *securely* close the tube e (fig. 1) at the top of the cistern. Then raise the reservoir. The mercury gradually rises in the cistern, and by compressing the air in the upper part is forced up the tube $a\,b$, and then filling the bulb sprengels down the tube $h\,i$. The reservoir may then be lowered on to its stand on H and the india-rubber stopper removed from the tube e. The reservoir is set in action by attaching a piece of india-rubber tube to the stopcock S and sucking out air until, passing down the tube l, it bubbles up through the mercury in the reservoir. Then close the stopcock, and adjust the reservoir at such a height on its stand that the mercury is nearly at the top† of the bulb in the distiller. If needful, a little more air is sucked out of the reservoir, as before described. Thus set in action, the level of the mercury in the cistern $c\,d$ will be retained constant until almost the

* So perfectly does this form of constant-level cistern work, that it seems probable that it may prove useful for other purposes—*e. g.* keeping a Sprengel-pump in uniform action for many consecutive hours &c.

† The vapour-tension of the hot mercury will depress the level in the bulb. The extent of this depression is somewhat dependent upon the height of the gas. On this account a simple form of gas-pressure regulator may be advantageously used with this apparatus. In another connection I hope to describe a pressure regulator of very convenient construction for this and other purposes.

whole of the contents of the regulating reservoir have been distilled.

To start the distillation, remove the tin plate which covers the cylinder (H) and light the gas. Five to ten minutes later, sufficient mercury will have distilled over to have entirely displaced the impure mercury originally present in the narrow Sprengel-tube *i*.

The reservoir can be replenished with mercury without interrupting the distillation. For this purpose it is only necessary to place a screw pinchcock on the india-rubber tube leading to the cistern of the distiller, open the stopcock S, and pour the mercury into the reservoir through the funnel *t*. Then suck a few bubbles of air out of the reservoir, as before described, close the stopcock, and release the screw-clamp from the india-rubber tube. The level of the mercury in the distiller will remain as before.

When it is desired to empty the distiller of mercury, air must be introduced into the bulb either by alternately sucking and blowing through a piece of india-rubber tubing connected with the end of *i*, or by disconnecting the india-rubber tube leading from the reservoir, emptying the cistern *c d*, and cautiously inclining the distiller until small bubbles of air enter at the end of the tube *a b* and rise into the bulb. The mercury then sinks into the cistern, and may be withdrawn through the tube *f*.

The Sprengel-tube *i* should be carefully cleaned and dried before putting the apparatus together.

The first time of using the distiller, it is interesting to observe that, as the tube *a b* gradually becomes heated, the surface air-film detaches itself from the glass and rises into the bulb.

The quantity of mercury distilled by an apparatus of the size and form here described is about 2 lb. an hour: very little gas is used, as the flames should be less than a quarter of an inch high and never allowed to come in contact with the glass bulb. For commercial purposes, an iron mercury-bottle and iron gas-pipe might advantageously replace the glass bulb and tube.

It seems to be possible that the latter modification of the method may be applicable to the distillation of some other metals, such as zinc, magnesium, cadmium, arsenic, &c.

XXXVIII. *On a Method of determining experimentally the Constant of an Electro-dynamometer.* By A. P. Chattock*.

The practical importance attaching to the accurate measurement of electric currents is daily increasing with the extended use of electricity. For this reason I venture to hope that the following account of some experiments on the calibration of an electro-dynamometer will prove interesting.

The twisting moment with which the fixed coil of an electro-dynamometer acts on the suspended coil is proportional to the product of the strengths of current flowing through the two coils respectively, and to a factor which depends on their geometrical relations.

If a current be sent through the fixed coil and the suspended coil be allowed to rotate, an E.M.F. is set up in the latter which is at any instant proportional to the speed of rotation, to the strength of the current in the fixed coil, and to a factor depending on the geometrical relations of the two coils.

By allowing the suspended coil to rotate about its axis of suspension, and by making the geometrical factor during rotation the same as afterwards, when the coil is suspended in its place, I have determined the constant of the instrument upon the table.

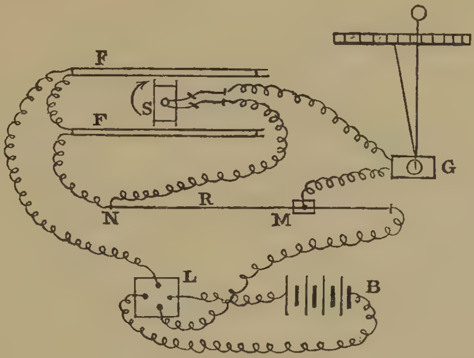
It is the method I employed in doing this which I have the honour of bringing before you to-day. The diagram shows the arrangement of the apparatus.

F, F are the fixed coils of the dynamometer; S the revolving coil to be afterwards suspended within them, and which makes contact once in every revolution with M and N; B a battery sending a current C through the coils F by the commutator L. G is an astatic mirror-galvanometer of about the same resistance as the coil S; and R is the resistance between M and N, adjustable by the slider M.

Let i be the intensity of the magnetic field, at the place where S revolves, due to unit current in the fixed coils F; H the horizontal intensity of the earth's magnetism at the same place; σ the effective area of the coil S; and k a factor depending on the relative positions of the two coils when the

* Read November 24, 1883.

revolving coil is in contact with M and N through G. $i\sigma k$ is then the geometrical factor referred to above.



Suppose the coil S rotates with an angular velocity ω, while a current of strength C flows through the fixed coils. An E.M.F. is set up in S equal to

$$Ci\sigma\omega k + H\sigma\omega k'.$$

If the resistance R between M and N be now adjusted till no current flows through G, this E.M.F. must be equal to the difference of potential between M and N due to the current, viz. CR; that is,

$$Ci\sigma\omega k + H\sigma\omega k' = CR.$$

Commutating the current at L and adjusting R, we get

$$-Ci\sigma\omega k + H\sigma\omega k' = -CR';$$

and from these two equations,

$$i\sigma k = \frac{R+R'}{2\omega}.$$

If, as is desirable, the instrument is set up so that the term depending on the earth's magnetism vanishes, we have simply

$$Ci\sigma\omega k = CR;$$

and the value of $i\sigma k$ being obtainable from one reading, there is no error due to variation of the current.

Having thus obtained the value of $i\sigma k$, the coil S is suspended within the coils F so that its axis of suspension coincides with its previous axis of rotation; and by means of sights, properly adjusted, it is brought into the same position relatively to F as it occupied when making contact with M and N.

If now an unknown current C be made to flow through the instrument, and the electrical turning moment of the suspended coil be opposed by an equal and opposite mechanical moment T in the suspension-springs, we have

$$T = C^2 i\sigma k + HC\sigma k';$$

and on commutation of the current,

$$T' = C^2 i\sigma k - HC\sigma k',$$

from which

$$C = \sqrt{\frac{T+T'}{2i\sigma k}} = \sqrt{t+t'}\sqrt{\frac{T_0}{2i\sigma k}} = \sqrt{t+t'}\,K;$$

where T_0 is the moment due to unit twist on the springs, and t the actual twist on them.

Here, as before, the instrument can be set up so that $HC\sigma k'$ vanishes, and a value of the current can be obtained in one reading.

The absolute value of T_0 can, of course, be found accurately by taking the time of vibration of a mass of known moment of inertia when suspended in the place of the coil S; and thus the constant, K, of the instrument can be determined.

There are two points in the practical carrying out of this method which require special attention—the prevention of thermal and other extraneous currents in the circuit of the revolving coil, and the keeping its speed uniform throughout each revolution. Success in both these cases depends chiefly on the manner of making contact between the revolving coil and the points M and N.

In my first experiments with the instrument I allowed the two ends of the revolving coil to touch, in passing, two fixed wires in connexion with M and N. After calculating a constant, I compared the instrument with the very accurate tangent-galvanometer belonging to University College, and found a difference of 6 per cent. between them, the readings on mine being the lower of the two.

Thinking that this discrepancy might be due to the speed at the moment of contact being greater than the average speed (which was all that could be measured), and that this difference,

again, might be due to the friction of the contact (as well as of another contact used for counting the revolutions), I substituted contact-rollers with platinum rims for the fixed wires. The axles of these rollers were vertical, and were furnished at their upper ends with mercury-cups into which dipped the wires connected with M and N. This was to avoid thermal currents. The rollers were pressed against the rim of an ebonite disk, fixed coaxially to the revolving coil. Into this rim were let two pieces of platinum, connected with the ends of the coil and making contact with the rollers as they passed them. The result of this alteration was that the difference between the readings of my instrument and the tangent-galvanometer was reduced to 1·5 per cent.

I have not been able to experiment further in this matter; but I believe that, by substituting for the rollers an arrangement of light levers, by which a bent wire could be lifted in and out of two mercury-cups with each revolution of the coil, thereby making and breaking contact, a still greater degree of accuracy should be attainable. The addition of a fly-wheel to the coil while revolving would also tend to keep the speed uniform.

A partial explanation of the disagreement of the two instruments may be found, too, in the fact that mine is home-made, and therefore not so well finished as it otherwise might be.

With the aid of a tangent-galvanometer of known constant, the dynamometer can be calibrated to give a convenient absolute measure of the horizontal intensity of a magnetic field. For this purpose the axis of the suspended coil must be at right angles to the direction of the magnetism.

The instrument is first set up in such a position that on sending a current through the suspended coil alone, no deflection is produced. It is then turned bodily through a right angle by means of a graduated foot, and in this position it is connected in series with a tangent-galvanometer and battery.

Let H be the strength of the field at the place where the dynamometer stands, and H′ the same where the tangent-galvanometer stands. Then, for a current C sent through both

instruments and commutated, we get from the dynamometer the two following equations:—

$$T = C^2 i\sigma k + HC\sigma,$$
$$T' = C^2 i\sigma k - HC\sigma;$$

from which

$$CH = \frac{T-T'}{2\sigma};$$

and from the tangent-galvanometer we have

$$\frac{C}{H'} = \frac{\tan\theta}{i'}.$$

Interchanging the two instruments and repeating the experiment, we obtain two similar equations with H and H′ interchanged. From which

$$\sigma = \frac{1}{2CC'i'}\sqrt{(T-T')(T''-T''')\tan\theta\,.\tan\theta'},$$

where every thing is known, the values of C and C′ being determinable by the dynamometer from the same readings. σ being once known, the horizontal intensity of a magnetic field is determinable by simply setting up the dynamometer so that the axis of its movable coil is at right angles to the meridian, as described above, and then sending the same current through it successively in both directions, the equation being

$$H = \frac{T-T'}{2\sigma C} = K'\,.\,\frac{t-t'}{\sqrt{t+t'}}.$$

A somewhat different use of the dynamometer for the same purpose is given by Kohlrausch in his ‘Physical Measurements,’ p. 180.

In conclusion I wish to thank Prof. Foster for his kindness in allowing me to test my instrument in the Physical Laboratory at University College. My thanks are also due to Mr. W. S. Grant for many valuable hints on the construction of the instrument.

XXXIX. *On certain Molecular Constants.*

By FREDERICK GUTHRIE.*

[Plates XV. & XVI.]

Liquid Slabs. Metallic Diffusion.

§ 1. *Liquid Slabs.*—When a little liquid is poured upon a flat horizontal surface which is not attacked by the liquid, a circular disk of liquid is formed, the shape of the edge of which has been very fully examined by Quincke and others. In most such cases, one of the most important factors is the specific relationship in the sense of adhesion between the solid and the liquid. In fact the question, like all questions of capillarity, involves density (and gravitation), cohesion, adhesion, and surface-tension. Such experiments show the relationship between two bodies as well as the physical attributes of one. About twenty years ago I made an attempt to get rid of the factor adhesion, with partial success, by examining the size of a liquid drop. But I soon found that other factors, notably the shape of the solid bodies from which the dropping occurred, and the rate of dropping, introduced arbitrary conditions which removed the measurements from the class of simple physical constants.

§ 2. The plan adopted in the following experiments is the endeavour to support a mass of liquid above a plane surface in such a way that no actual contact ensues, not even such as takes place between clean glass and mercury. If such can be done, it is clear that we shall have a circular flat slab with rounded edges, and into the shape of that slab the influence of adhesion by no means enters. If the thickness of the slab be found to be a constant, we shall have a constant as characteristic as density, and, like density, varying for the same mass only according to volume, such volume-change in our case being brought about by heat alone. Such slab-thickness has for its negative influence the action of gravity (density), for its positive the cohesion and surface-tension.

§ 3. The actual measurements of the slab-thickness I have performed in two ways :—(1) by a spherimeter which, when used as such, gives results trustworthy to the $\frac{2}{10000}$ of an inch.

* Communicated to the Physical Society during the Session 188283.

But the upper of the two surfaces whose distance has to be measured being liquid, and the lower one not very hard, the spherimeter cannot be used by the method of touch. Accordingly I have measured the slab-thickness indirectly. A known volume of the liquid is poured on the surface, and teased into the circular form if it shows any noticeable departures from it. Four or five diameters are measured by means of a small horizontal cathetometer. The mean being taken, an allowance has to be made for the meniscus. This reduces the shape to the cylindrical, from which the thickness h is deduced by means of the equation

$$h=\frac{V}{\pi r^2}.$$

§ 4. In regard to the actual apparatus:—Upon a thick round slab of paraffin, a foot in diameter and 4 inches thick, a massive foot of plaster is cast. The whole is placed on a three-screw levelling support. The surface of the paraffin is scraped into a true plane. When water was being examined, the surface of the paraffin was lightly powdered with lycopodium and the water poured on vertically from a fine opening. With some care a perfectly round slab of water 6 inches in diameter can be formed, which is so free to move that the greatest nicety of adjustment in the levelling-screws is necessary. Precisely the same arrangement can be adopted for mercury. But it was found that for the latter liquid a sheet of blotting-paper wetted and allowed to dry on a sheet of plate-glass gave results identical with those of the paraffin surface. The paper surface was used in some of the experiments. As to the allowance for the meniscus, it is clear that this is of less consequence with large slabs than with small ones. Indeed, with slabs a few inches in diameter the meniscus might be neglected. This was imperfectly shown in the case of mercury by adding exactly equal volumes to a small slab. After the slab had passed 2 inches in diameter, each additional volume produced a "parabolic" increase in the diameter. Data derived from this and from the measurement of an enlarged photograph of the edge gave me as a mean 2 millim. to be deducted from the diameter in the case of mercury. Assuming it to be the same for water,

the error incurred, after making this reduction, could not in a 6-inch slab be more than $\frac{1}{500}$ of the diameter. This would be negligible in the deduced thickness.

§ 5. I give the following datum for mercury on account of the accidental coincidence of the experimental numbers with numbers easy of remembrance, excepting as to the temperature, which is, however, not far from the conventional temperature of 60° F.

100 cub. centim. of mercury at 14° C. has an extreme radius of 100 millim.

$$h = \frac{100{,}000}{3{\cdot}1416 \times 99^2};$$

thickness of mercury slab = 3·248 millim.

In the case of water it was found so difficult to get a nearly circular slab with 100 cub. centim., that only 50 were employed. The slab may then be teased into a circular form by means of a stick of paraffin covered with lycopodium.

50 cub. centim. of water at 14° C. has an extreme radius of 54·8 millim.

$$h = \frac{50{,}000}{3{\cdot}1416 \times (53{\cdot}8)^2};$$

thickness = 5·50 millim.

Glycerine * is a beautiful liquid in this respect. It is kept off from the paraffin surface by a very faint blush of lycopodium, and it travels very slowly. It can be got into a circular slab more easily than water; but, perhaps on account of its capillary action towards its lycopodium props, it is more persistent in its motion. In fact, unless there be hills of that substance to confront it, it rolls along (for that is the motion of a slab however large) and forms a "level," which requires a very steady support to avoid the notion that its motion is affected by the gravity of the observer.

50 cub. centim. of glycerine at 14° C. has an extreme radius of 59 millim.

$$h = \frac{50{,}000}{3{\cdot}1416 \times (58)^2};$$

thickness = 4·731 millim.

* Commercial, "Price's."

§ 6. Accordingly, taking the slab thickness of water as unity, we may begin a table which will at some future time assuredly be extended.

Specific Slab-thickness (at 14° C.).

Water .	=1·0000,
Glycerine	=0·8602,
Mercury	=0·5906,

These numbers may be, with instruction, considered in reference to the numbers in table vii., which concern the drop-sizes of the same three liquids, in the 'Proceedings of the Royal Society,' 1864, p. 17 [" Recess "]. It will, I have no donbt, appear that in all cases the greater the drop-size the greater the slab-thickness. Water will, no doubt, again assert its singularity and exhibit the greatest slab-thickness.

§ 7. Restrained as slabs are in their form by skin-tension as well as cohesion, it is found that the addition of a liquid which diminishes the former diminishes also the slab-thickness. Taking 25 cub. centim. of water at 14° C., a slab was formed having 38 millim. corrected radius. This gives a thickness of 5·51 millim. Such a slab is unchanged if touched in the middle by a drop of glycerine. But on touching it with " glacial " acetic acid, it instantly acquires a corrected radius of 44 millim., or thickness of 4·16 millim. This means a diminution in thickness of very nearly 25 per cent., or one quarter. The question therefore presented itself, What is the slab-thickness of " glacial " acetic acid ?

I reserve the results of my experiments in the direction of the relationship between the liquids and the alteration of skin-tension.

§ 8. The mercury slab, like the water slab, has what virtually amounts to a skin; and it became interesting to examine the conditions of this skin or region of surface-tension. If lycopodium be strewn upon the surface of a mercury slab, and a little tin, zinc, or lead, or amalgam of these metals be made to touch the slab in the middle, no noticeable disturbance takes place. But if such a slab be touched by an amalgam of K or Na, the slab instantly expands, and the film of lycopodium-powder on its surface cracks radially, exposing the

brilliant metallic surface, which is seen to be agitated over its whole extent. In a few seconds the slab contracts to its original size and the lycopodium cracks heal.

Does this extension of the slab depend upon the diminution of the cohesion of the mass of the mercury, or upon a surface effect?

§ 9. I frequently in my researches have had recourse to the fact, which I first described in the year 1863, that a little sodium added to mercury enables that metal to touch with positive capillarity metals which in its and their ordinary state are not wetted by the liquid metal. I here make use of the same fact. A platinum tube (fig. 1, Pl. XV.), 6 millim. in internal diameter and 2 centim. in height, is rubbed and soaked in some weak sodium amalgam, and then washed in several quantities of pure mercury. Placing such a tube vertically in the middle of a slab of mercury so that its lower edge is clear of the surface upon which the mercury slab rests, we have the condition shown in fig. 1. A little grain of sodium amalgam dropped into the platinum tube causes no immediate change; but in a time measurable by seconds, say 20 to 30 seconds, the slab starts on its expansion and reaches its maximum size, apparently immediately. It seems, then, that since the effect is not instantaneous, it is a surface effect. The effect when produced is due to an alteration of the surface between the tube and the outer portion of the slab. By dipping the platinum tube further down into the slab so as to be within $\frac{1}{50}$ of an inch of the bottom, I have found the effect to be distinctly delayed.

§ 10. The fact mentioned in § 9, that the release of the mercury skin-tension by sodium is brought about after a time, short indeed, but appreciable when introduced into the central part of a liquid slab inside the platinum tube, points to the existence of a true diffusion between the metals; and this leads to the second part of this communication. For I have examined already a few such cases, which I will now describe, because I believe the subject of elementary diffusion has been neglected excepting in the case of gases, and even here but little is really known.

§ 11. *Metallic Diffusion.*—The metals potassium and sodium suggested themselves of course at once. They offer excep-

tional facilities for the determination of the composition of the mixture, when they have diffused through mercury, because the mere addition of water translates the alkaline metal into hydrogen. The neutralization of the alkalized water, say, by hydrochloric acid, and subsequent evaporation and weighing, give a control upon the hydrogen translation of the alkaline metal. The mercury is thereupon left nearly ready for weighing.

On the other hand, I have not yet been able to establish a column of mercury having an unlimited stock of pure cold alkaline metal above pure mercury at the same temperature below. I do not see the possibility of it. Granted that when such metals as tin, or lead, or gold, or silver dissolve in mercury, heat may move, such movement of heat is, I should think, swamped in its power of causing convection-currents by the conductivity of the mass. But in the case of the alkaline metals the first contact of the two metals is accompanied by so much heat that the conditions obtainable with other metals are here far more difficult. Perhaps mercury and sodium brought into contact at a temperature far below the freezing-point of mercury might give the required starting-point. If their contact were real and the elevation of temperature very gradual and well controlled, we might have a trustworthy condition ; but scarcely so at a single temperature.

Such a condition would represent a certain fixed sodium potential (not infinite, because the sodium has to be disintegrated), on the one hand, and a lower, but not zero, on the other ; and between the two the integral of the resistances of the various amalgams after the first contact.

§ 12. This being so, I elected to employ sodium amalgam and potassium amalgam rather than the free metals.

On mixing sodium with mercury, the two combine with great energy and liberate so much heat as to point to a loss of volume. Is this loss of volume, if it take place under any circumstance, so great as to give rise to an amalgam having a greater density than mercury itself?

If $\frac{m_1}{v_1}$ be the density of mercury and $\frac{m_2}{v_2}$ that of sodium, and if v_3 be the volume of the amalgam, then the density of

the amalgam would be equal to that of the mercury, if

$$\frac{m_1+m_2}{v_3}=\frac{m_1}{v_1},$$

or

$$v_3=v_1\left(1+\frac{m_1}{m_2}\right).$$

If v_3 should be less than this for any ratio between the constituents, the convection-currents of sodium would at all events begin to flow down if such an amalgam were at the top of the mercurial column.

On this point, without making a study of the specific gravity of alloys of sodium of different strengths, I have satisfied myself that, as long as the amalgam is liquid, it is lighter than mercury. This is easily shown by introducing mercury into one limb and the various liquid amalgams of sodium into the other limb of a long U-tube : whereupon the pure mercury always prevails in weight. Now when a solid amalgam of sodium is brought into contact with mercury, heat may be either set free or absorbed. Chemists will understand me if I remind them that a pounds of water mixed with b pounds of chloride of calcium will give a body which will set free or absorb heat according as a is greater or less than x.

§ 13. Accordingly I made a pound or two of a sodium amalgam of such a strength as to be solid at the atmospheric temperature. This was beaten up in an iron mortar as it cooled. Putting some of this into a porcelain crucible, plunging it into water containing a few drops of hydrochloric acid, and collecting the hydrogen, it was found that after a day or two, if the amalgam was occasionally stirred, all evolution of hydrogen ceased ; the volumes, reduced to dry hydrogen at 0° C. and 760 millim., were $\left\{\begin{matrix}156\\128\end{matrix}\right\}$ cub. centim. The mercury, after drying, was found to weigh $\left\{\begin{matrix}15{\cdot}1096\\13{\cdot}7841\end{matrix}\right.$. This gives the percentage of the amalgam, which I shall call A*m* amalgam :—

Hg.........	98·2	97·97	98·08
Na.........	1·8	2·03	1·92
	100·0	100·00	100·00 (mean)

The ideal amalgam would perhaps be one of such a composition that heat would neither be set free nor absorbed on

further mixing with mercury. But such an ideal condition could only be ideal in its beginning, and, I think, disturbances due to this cause are insensible in comparison with other sources of error. The above amalgam, when stirred with mercury, may reduce its temperature as much as 5° C.

I am informed that sodium may contain a large quantity of hydrogen. I am not called on to discuss the experiments (not my own) upon which this rests; but I think that any considerable quantity would be expelled on amalgamation. Perhaps the glow or blush to be described immediately and in § 14 is due to the escape of residual hydrogen at the released tension-surface of the mercury.

The first experiment in regard to the diffusion of sodium out of this amalgam into mercury was of course a qualitative one. A U-tube (fig. 2, Pl. XV.) was made of glass tube of $\frac{1}{2}$ inch internal diameter—the one limb, A, being about 3 inches and the other, B, about $2\frac{1}{2}$ inches long, reckoned from the inner bend a. This was fastened into a massive fusible metal foot to give stability. The U-tube was dried perfectly under the ordinary air-condition, and received pure dry mercury, which stood in both limbs at a height of about $2\frac{2}{5}$ inches (reckoned from a). The whole was placed in a flat-bottomed vessel g containing a little melted paraffin, and then upon an immovable slab, to which it was stuck by a few drops of paraffin. The vessel g then received water slightly acidulated with HCl so as to cover the mercury in the shorter limb, and reach about $\frac{1}{4}$ inch above the edge of the glass tube on that side. A test-tube filled with similarly acidulated water was inverted over the shorter limb. Upon the surface of the mercury in A about 15 grams of the amalgam Am was placed; this was covered with petroleum, and the tube was plugged with cotton-wool.

Immediately after introducing the sodium amalgam a kind of frosted appearance is seen on the immediately lower parts of the mercury and glass surface in A. This appearance, which is a blush of bubbles, creeps downwards with strange rapidity, reaching the bend, say $2\frac{4}{10}$ inches, in a quarter of an hour.

In about 30 hours, bubbles of hydrogen appear at the surface of the mercury in B and collect in the pneumatic tube. Such evolution continues sensible for about a month. After two months such evolution ceased, the contents were emptied

out, thereby being of course mixed, and no further evolution of hydrogen could be detected.

Such a method of experimentation is, however, far from quantitative, because when the sodium has diffused down through A as far as *a*, it will, being lighter than mercury, rise through B and cause whirls.

The ideal condition of such diffusion would be of course similar to the ideal condition of heat- or electrical transference, where one may have a given potential at one end of the column, and a given lower one, fancifully called zero, at the other.

Perhaps this condition is to be attained with the greatest practical completeness by the simple *long* vertical column.

§ 14. Three glass burettes were made, about a foot in length and an inch in internal diameter. They were drawn out sharply at the bottom into capillary tubes, upon which pressure-taps were fixed in the ordinary way. These were nearly filled with pure mercury. A little of the mercury was allowed to run through so as to fill the capillary and caoutchouc tube.

Upon a tube so prepared and filled, about 15 grams of the amalgam A*m* were placed. The amalgam was thereupon covered liberally with petroleum ; and the top of the tube was slightly corked. Instantly clouds of minute bubbles began to make their appearance between the mercury and the glass. In half an hour the whole column appeared frosted (see § 13). On drawing off a measure, say $\frac{1}{13}$ of the whole, from the bottom after two or three hours, no appreciable amount of hydrogen was to be got from it.

Accordingly the tube was reemptied, cleaned, dried, and refilled. · The amalgam (A*m*) was then allowed to rest upon the top for 14 days and nights in an undisturbed and steady place, where the temperature ranged from 13° to 18° C. At the end of this time the amalgam was drawn off. The drawing off was effected as follows :—A little block of paraffin was hollowed so as to have a smooth cavity of the capacity of about $\frac{1}{13}$ of the tube in fig. 3. The edge was ground flat, and a flat slab of paraffin served as a cover. The amalgam was drawn into this very slowly so as to stand above the edge ; the slab being then pressed down, a unit volume was entrapped. This being transferred to a porcelain capsule, the few drops of

overflow were returned to unit measure, which was again filled up, and so on. The six lowest measures (each about $\frac{1}{13}$) did not show a trace of hydrogen. The seven higher ones evolved hydrogen in the quantities shown in the following table, in which the actual weights of the mercury are reduced to 100, the cub. centim. of hydrogen being recalculated and reduced to dry hydrogen at 0° C. and 760 millim. It appears that in 14 days the sodium had penetrated down a little more than halfway, say 7 inches, in quantity appreciable.

I put now these results in such a form that they may be, as far as possible, immediately comparable with the results obtained by other metals. They come out as follows :—

Per cent. Na.	Hg.		Na.
·0035............	100	and	·0035
·0178............	„	„	·0178
.0665............	„	„	·0666
·1769............	„	„	·1772
·2034	„	„	·2038
·2295............	„	„	·230
·2414............	„	„	·242

§ 15. A potassium amalgam prepared in a similar manner was found, when analyzed as in § 13, to have the composition 1·34 per cent. of K. About the same quantity of this was put into the same tube as had been used for the Na, under, as far as possible, the same conditions.

Reducing the evolved H to 0 and 760, as before, it was found that the 13 volumes of the column (all of which were nearly equal except the last, which, instead of about 84–82 grams of mercury, only held about 52, for this was the drainage from the amalgam), had the composition :—

Per cent. of K.
0·00082
·0038
·0146
·0331
·1185
·2061
·2811
·3490

As to the comparison between Na and K, we need only contemplate the potential-difference between 1·92 and 1·34 respectively.

With regard to the frosted appearance mentioned in §§13, 14, it can scarcely be doubted that the minute bubbles which compose it are hydrogen, due to the film of water or vapour on the glass. But while this appearance travels at the rate of at least one foot an hour, there is no sensible quantity of Na to be found at even a lesser depth after fourteen days. The effect must therefore be a surface-effect, and be of the same order as the effect described in § 8, where the mercury-slab expands when touched by sodium amalgam, on account of metals spreading almost instantaneously over its surface and enfeebling its skin. The condition actually set up in the mercury column is probably this :—A minute film of sodium spreads downwards between the mercury and the glass : this decomposes the water on the glass, and so clothes the glass with a film of minute hydrogen bubbles, and the mercury surface with a film of caustic soda, which latter is in absolute contact with the mercury surface. It is a question whether the sodium film is less than, equal to, or more than sufficient to decompose the water—probably more. At all events it is so minute as not to exhibit itself in any chemical reaction. The spectroscopic reaction here has no significance.

The curves Na and K, Plate XVI., which represent these experiments graphically, are not directly comparable with the curves Sn, Pb, and Zn (§ 17) in the same plate, because in the case of Na and K, for reasons given in § 11, it was found necessary to start with an amalgam, and indeed with one containing only about 2 per cent. of sodium. The time in the case of the Na and K amalgams was also a little less than half that occupied in the diffusion of Zn, Pb, and Sn.

§ 16. The rapid penetration of zinc by mercury suggested the question whether, when an amalgam of an alkaline metal was presented to zinc, the mercury would penetrate the zinc and carry the alkaline metal with it. Accordingly the above potassium amalgam was introduced into a hollow cylinder of cast zinc, 17 millim. internal, and 21 millim. external diameter (thickness 2 millim.), 45 millim. external height, 35 millim. internal height (10 millim. thickness of bottom). The

amalgam was scraped upon the zinc so as to ensure contact, and then covered with petroleum. The zinc cylinder was thereupon corked up and the cork covered with paraffin. It was placed in a beaker of distilled water and covered with a tube of water according to fig. 4, Plate XV. After two months' standing at a uniform temperature of about 15°, scarcely a pin's-head volume of gas had collected in the top of the tube. Abundance of the semiflocculent fine oxyhydro-carbonate had collected on the zinc and at the bottom of the beaker. That part on the zinc was rubbed off the zinc with an ivory blade, and, together with the sediment in the beaker, dissolved in hydrochloric acid overneutralized with ammonia and sulphide of ammonium. After separation of the Zn, no trace of K could be found. No potassium had found its way through the zinc. Perhaps a more remarkable fact still is this, that on scraping about a gram of the solid metal from the outside of the zinc cylinder, not a trace of mercury could be found in it. Not only, therefore, did the alkaline metal fail to follow the mercury into the zinc, but it prevented the mercury from entering the zinc. Compare this with § 18, where the cylinder of zinc is literally "slaked" by the mercury.

§ 17. Cylinders of zinc, lead, and tin were cast, an inch and a quarter long and $\frac{7}{8}$ inch in diameter. These were floated on the mercury contained in the tubes described in § 14. The quantity of the mercury in each tube was such that it stood at the same height, reckoning from the bottom of each cylinder. The burettes had been previously lashed to massive stands, cork buffers being interposed between the tubes and the stands. The three were placed side by side on a slab let into the wall, and were protected as much as possible by cloths from sudden changes of temperature. The mean temperature was 15° C. The experiments lasted a month, and the extreme range of temperature was from 13° C. to 17°·5 C.

At the end of the month (31 days) the mercury was run off from the bottom very slowly and discontinuously into the paraffin vessel described in § 14; so that, with the exception of the top quantities, the volumes of the successive portions were very nearly the same. With regard to the top quantities, it is clear that, since the metals float at different depths in the mercury, the surfaces of contact are not the same in the

several cases; and therefore these top, or richest, amalgams can scarcely be compared. Again, the shape of the bottom of the tube with its capillary &c. puts the lowest or poorest out of court. But as the contents of the lower, irregular part of the tube is not more than a third of the volume of the unit measure, it is only the very lowest amalgam that need be rejected.

In each case there were twelve full unit vessels drawn off, and in each case a fraction of a thirteenth, which last contained the drainage from the metal.

Through the kindness of Dr. Hodgkinson a number of these amalgams were analyzed in the chemical laboratory by Messrs. Adie, Gahan, and Grange, to whom I am therefore indebted. These three gentlemen analyzed the zinc, lead, and tin amalgams respectively. The metals were determined in the following manners:—

Lead.—The amalgam dissolved in nitric acid and evaporated with sulphuric acid, and the residue either ignited directly or after washing with dilute alcohol (as sulphate of lead).

Tin.—The amalgam dissolved in nitric acid, evaporated to dryness, and ignited (as metastannic acid).

Zinc.—(α) By dissolving in nitric acid, evaporating to dryness, and igniting; or (β) by separating the mercury as sulphide and the zinc as sulphide, and igniting (both as oxide of zinc).

§ 18. In Table I. the results of such determinations are given, so that the proportion of the errors of analysis may be compared with the true diffusion in each, and the difference of diffusion in the three cases.

At the end of the experiment the cylinders of tin and lead presented nothing remarkable in appearance. On standing a couple of months the upper part of the lead cylinder has become as hard as zinc, though there is no sensible deformation. The zinc cylinder swelled considerably in the tube; and when left to itself afterwards, though drained from the mercury, it continued to swell and crack, and ultimately fell to pieces like a "lime-light" lime-cylinder when slaked. Two cones with their apices towards the centre of the cylinder were formed at top and bottom; the cracking otherwise was for the most part in radial planes.

In Plate XVI. the percentages of metal in the several amalgams of the three metals are given graphically, and without founding-off or other interpolation. The abscissæ reckoned from the left are distances from the bottom; the ordinates are the corresponding percentages of the respective metals.

TABLE I.

	Zinc.	Per cent.	Lead.	Per cent.	Tin.	Per cent.
1 (bottom).	0·064 0·062	0·063	0·188 0·204	0·196	0·13 0·21 0·174	0·171
2.	0·076 0·080	0·078				
3.	....		0·243 0·225	0·234	0·28 0·30	0·29
4.	0·126 0·117	0·122				
5.	....		0·303 0·274	0·289	0·38 0·41	0·40
6.	0·214 0·183	0·199				
7.	....		0·402 0·403	0·403	0·63 0·62	0·63
8.	0·254 0·266	0·260				
9.	0·337 0·338 0·325	0·333	0·609 0·646	0·628	0·99 1·01	1·00
10.	0·408 0·365	0·387				
11.	0·468 0·454	0·461	1·03 0·94	0·99	1·68 1·41 1·25	1·45
12.	0·573 0·569	0·571				
13 (top).	0·618 0·735	0·677	1·38 1·47	1·43	1·86 1·87 1·76	1·83

§ 19. It appears accordingly that the three metals lead, tin, and zinc, all of which and all of whose amalgams are

lighter than mercury, diffuse downwards through this latter metal in such a fashion that they appear, after a month's interval, in appreciable quantity at a depth of a foot beneath the surface when the temperature is about 16°–17° C. With regard to this latter point, as to temperature, I suppose that mercury is so good a conductor of heat that the influence of convection-currents is at least as inconsiderable as in the experiments which have been performed for determining the diffusion of soluble salts in water It is scarely worth while amusing oneself by dividing these diffusion *percentages* by the so-called "atomic weights" of the metals. A more serious consideration might be the result of the division of the diffused weight by the specific gravity of the metal. Comparing the numbers of the group Sn, Pb, and Zn with one another, we may remember that the metals are all cast, and therefore so far indefinite in structure. This may be especially the case with zinc, which cracks and thereby allows the mercury to rise by capillarity and so enrich itself, and generally set up conditions of amalgamation which I do not care to trace, for I do not see my way through.

As to the comparison of the alkaline group with the Sn, Pb, Zn groups, such comparison must be vague, for the reason that the K and Na are employed as amalgams (as though one would study the diffusion of nitre into water by employing a solution of nitre containing only 2 per cent. of the anhydrous salt); whereas the Sn, Pb, and Zn are used with what was supposed to be a sufficient supply of pure 100-per-cent. metal. But this imperfection of these conditions is manifest if we remember that while the solid metal melts and dissolves downwards, the liquid mercury rises. Accordingly there is, after the first instant of contact, supposing the metals diffuse, no constant metallo-motive force in the same place.

§ 20. I conclude therefore that the general curve of amalgamation, and therefore of alloyage, and therefore perhaps of elementary atomic and molecular diffusion generally, is of the kind shown in fig. 5, Pl. XV. In the case of Na almost the complete curve was obtained; whereas in the case of Zn the point of contriflexure had not been reached. The very fact that the K and Na curves are more complete in this fashion than the Pb, Zn, and Sn, prove to my mind that K and

Na have a far greater diffusive energy than the heavier metals examined. And although in this case the percentage of metal actually found at a given depth was in all cases much less than the percentages of the heavier metals, it will be borne in mind that, while the latter were pure and had acted for thirty-one days, the former were amalgams containing less than 2 per cent. of the metal. Comparing K with Na, I do not think we can draw any conclusion beyond the rather negative one, that the superior diffusive faculty which seems to be the property of K salts in regard to water does not evidence itself, if it exist, when that metal and sodium are compared in respect to their diffusion in mercury. I am far from asserting that such preeminence may not exist; but I do not think that it is here made conspicuous.

My friend Prof. Chandler Roberts has for a long time been engaged in studying the diffusion of melted metals, and the matter has been a subject of frequent conversation between us. I await with great interest the details of his experiments. The relative dates of our publication have no relation to the dates of our experiments.

XL. *On a new Insulating Support.* *By* Professor SILVANUS P. THOMPSON, *B.A., D.Sc.**

[Plate XVII.]

INSULATING supports consisting of rods rising through the necks of glass jars containing concentrated sulphuric acid, for the purpose of absorbing moisture which otherwise would condense upon the glass, appear to have been first introduced in practice by Sir William Thomson†. Similar devices have been more recently designed by Mascart‡, by Professor Clifton§, and by Professors Ayrton and Perry. The apparatus of Mascart differs only from the original design of Sir W.

* Read December 8, 1883.

† Proc. Roy. Soc. June 1867, and 'Reprint of Papers on Electrostatics and Magnetism,' p. 322. See also the figure given on page 14 of Maxwell's 'Elementary Treatise on Electricity.'

‡ *Journal de Physique,* t. vii. p. 217 (1878); 'Nature, xviii. p. 44 (1878); see also Wiedemann's *Electricität,* Bd. i. p. 16.

§ Proc. Roy. Soc. No. 182, p. 300 (1877).

Thomson in having the central support of glass solidly fused to the bottom of the jar which holds the acid, and in having the jar formed with a narrow neck instead of a wide one. This construction, though convenient in point of portability and solidity, renders necessary the addition of a tubulure at the side of the vessel by which to introduce the acid. The cost of the apparatus, which cannot be made except by a professional glass-blower, is consequently considerable.

Such supports are, in spite of their cost, of so great utility, especially in a humid climate, that a cheaper substitute of equally high insulation is a desideratum. In the electrical laboratory of University College, Bristol, insulating supports of the type about to be described are found of very great use.

A piece of combustion-tube, about 20 centim. long and 1·4 centim. diameter, is fused together at one end, and the closed end is slightly enlarged by blowing, and then slightly flattened at its extremity. This tube, which forms the central support, is placed upright in a wide-mouthed bottle of hard white flint-glass about 10 centim. high and 5·5 centim. diameter, in which about 50 to 70 grammes of paraffin-wax have been melted. When the paraffin solidifies it contracts greatly; but if the bottle be not too large, holds the stem firmly in its place. To keep out the dust a lid, formed from a disk of gutta-percha about 2 millim. thick, softened by dipping into boiling water, is placed loose-tight on the stem. The arrangement is shown in fig. 1. The upper end of the central tube is open, and affords a convenient means of placing on the support various different objects, such as a metal ball fixed on a metal rod, or a flat metal plate on which to stand any object that is to be insulated. For carrying wires over a table in experiments requiring high insulation, rods of flint-glass of 25 to 30 centim. length, curled at the top in the form of a crook or other hook-form, as shown in figs. 2 to 5, are placed in the central tube of the insulating support, and the wires are slung in them. The insulation-resistance of these supports is many hundreds of megohms even in damp weather. Should a film of dust accumulate on the surface of the paraffin in consequence of any neglect in lowering the gutta-percha cap, the insulator only requires to be warmed to the melting-point of paraffin to restore the lost insulation. For work requiring very special

insulation, sulphuric acid is poured over the top of the paraffin; and in some cases solid stems of glass have been used instead of glass tube. Hitherto there has been no trouble from yielding in the paraffin, which was feared at the outset as a possible fault. A good hard paraffin has been used; and as the flattened form given to the basal enlargement of the glass tube constitutes in itself a foot to the central support, there is little or no tendency for the paraffin to bend under the weight that may be placed for a few hours on the top of the support. To add stability to the apparatus, the bottle is let into a wooden foot. The total cost of the apparatus is less than one tenth of the price charged for the apparatus of Mascart.

NOTE.

In Mr. Glazebrook's Paper on "Curved Diffraction-Gratings," read 14 April, 1883, he gives a geometrical construction for a diffraction-grating without aberration (pp. 251, 252 of this Volume). This construction had previously been given to the Society by Professor Rowland as part of a verbal communication made on 11 Nov. 1882; but Mr. Glazebrook, not having been present on that occasion, was not aware that he had been anticipated on this point. No manuscript of Professor Rowland's communication was sent to the Society, and so the resemblance between his and Mr. Glazebrook's communications in this particular matter escaped notice, until pointed out by Professor Rowland, after Mr. Glazebrook's paper had been published.

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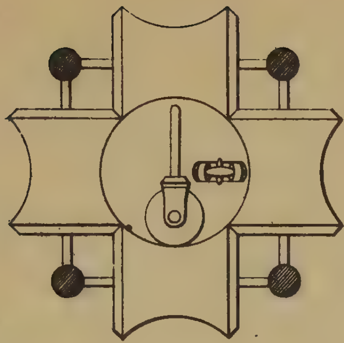
Fig. 12.

Mintern Bros. lith.



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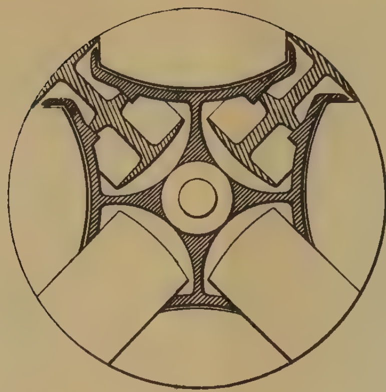

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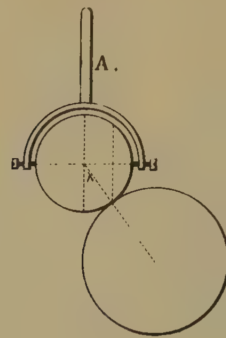

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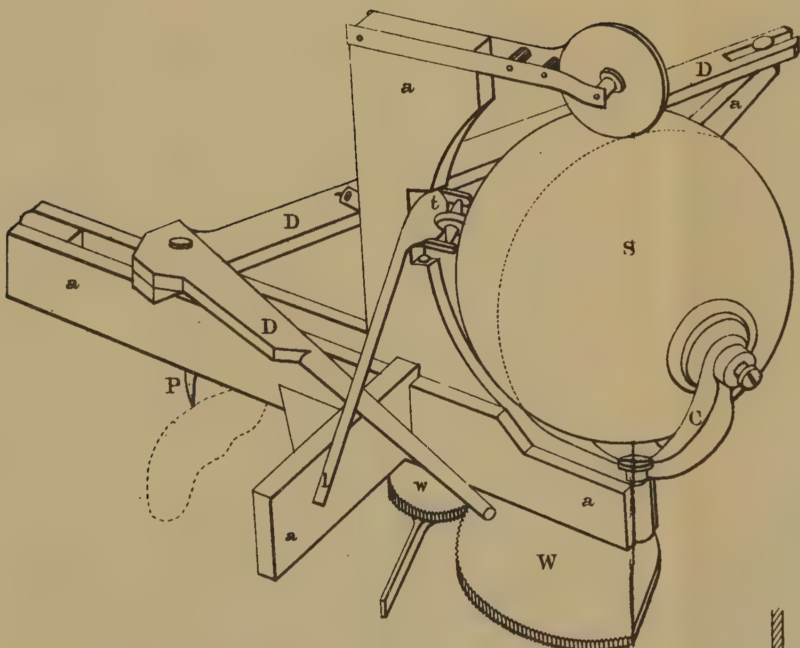

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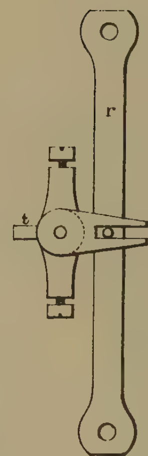

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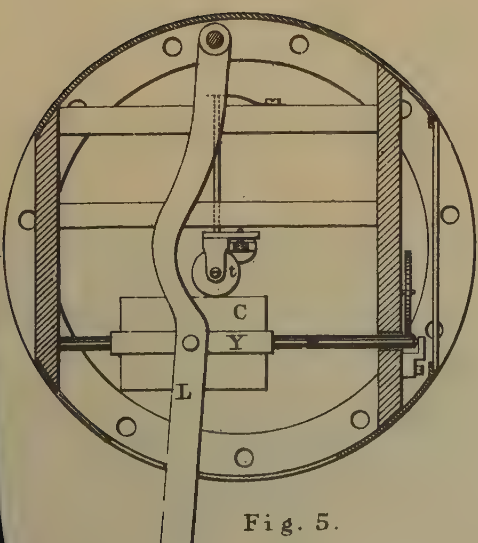

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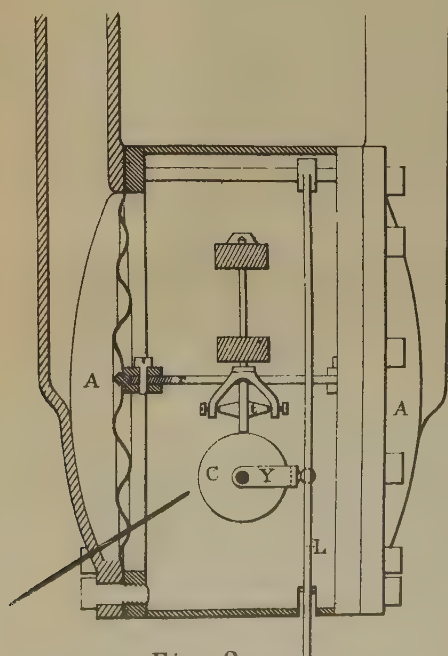

Fig. 6.

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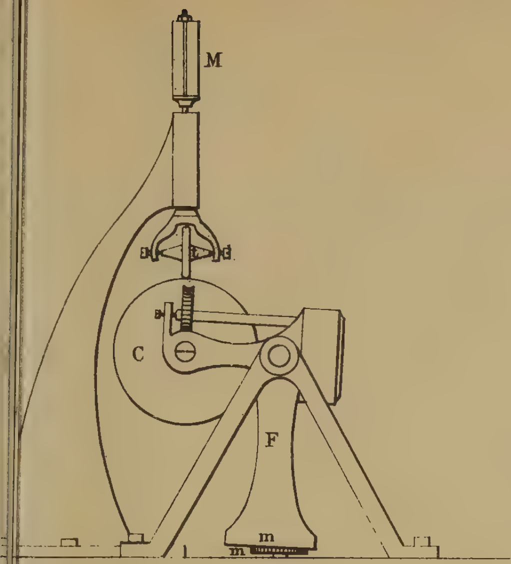

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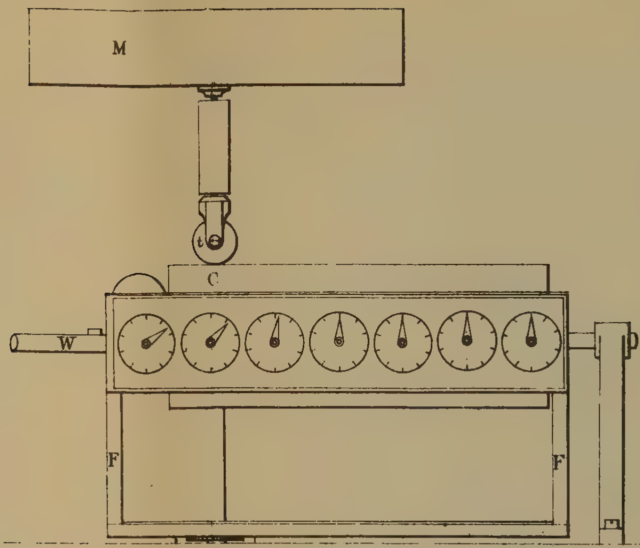

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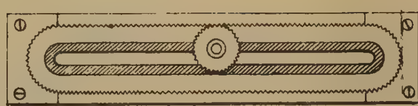

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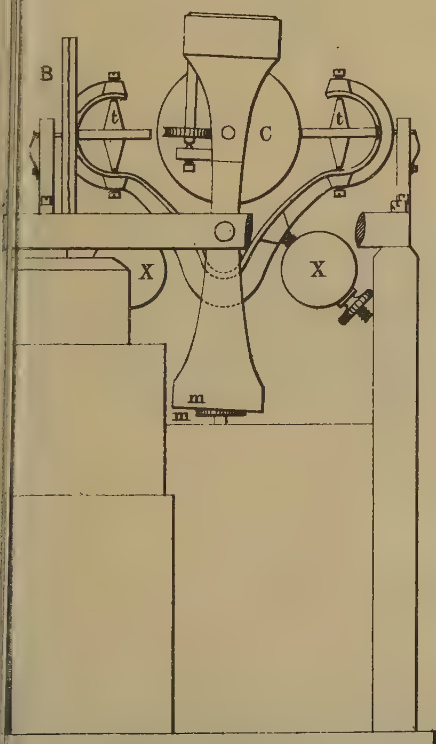

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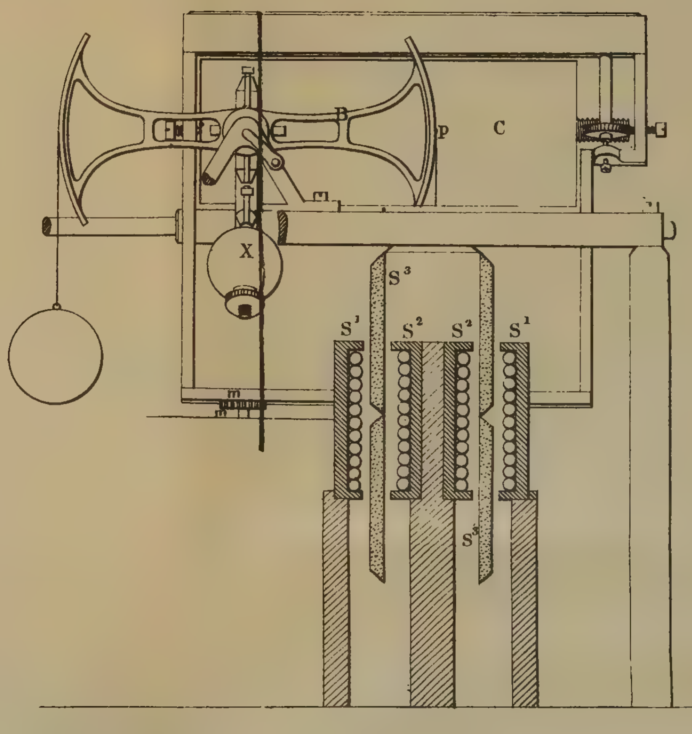
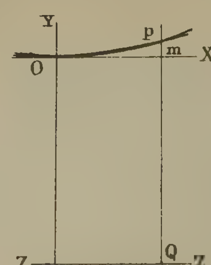


Fig. 12.

Fig. 13.

Fig. 14.



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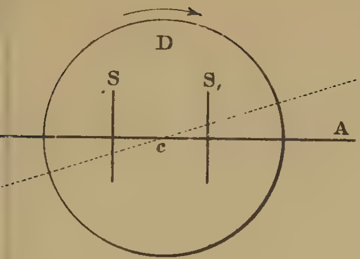

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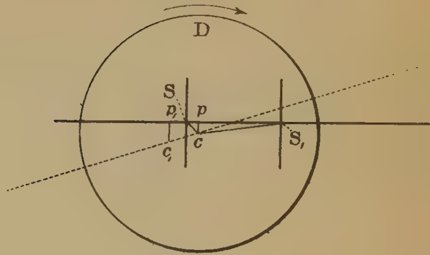

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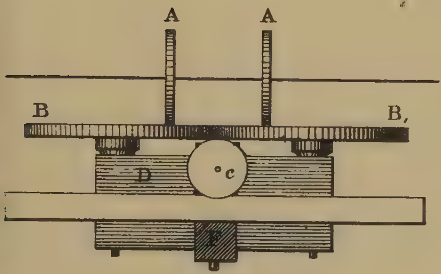

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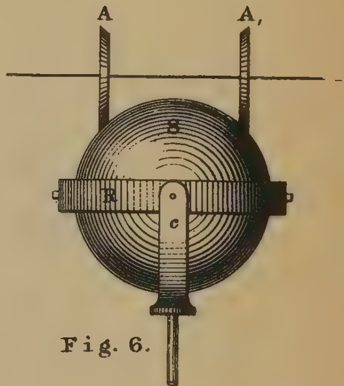

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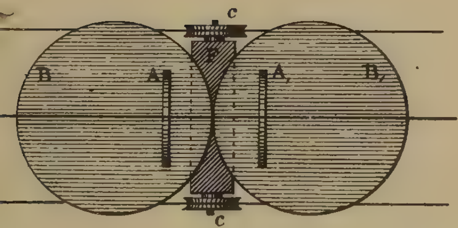

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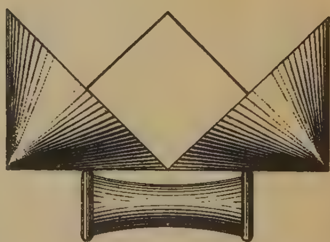


Fig. 7.

Mintern Bro's lith.

DIAGRAM Nº 1

May 6th 1881

Experiment on 3" Lead Balls melted in Fluid Lead.

Note. *The lead was very hot during Expt. 43. and gradually cooled during Expts. 44 & 45.*

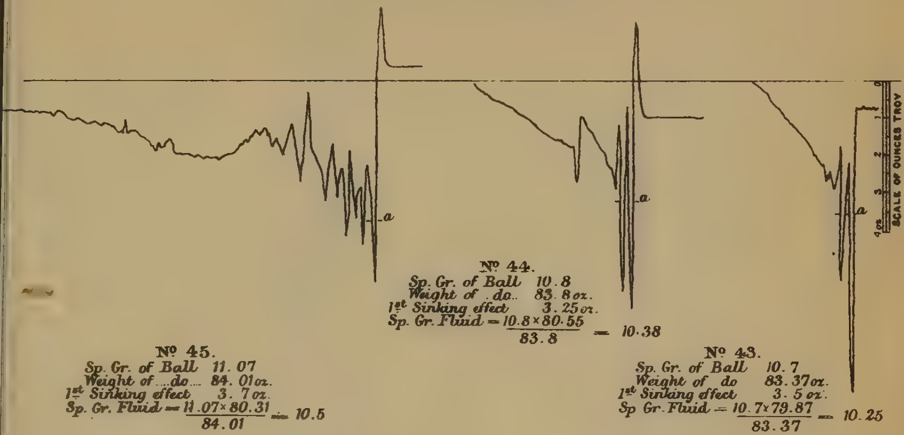


DIAGRAM Nº 2.

May 18th 1881.

Experiment on 3" Tin Ball melted in Fluid Tin.

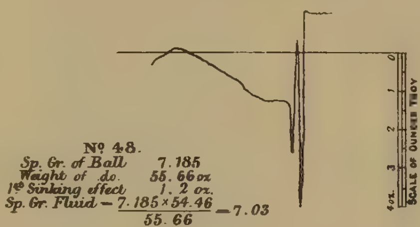
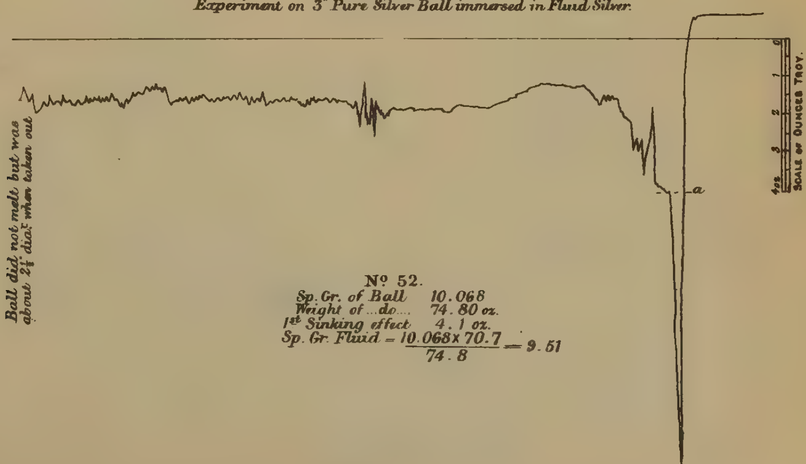


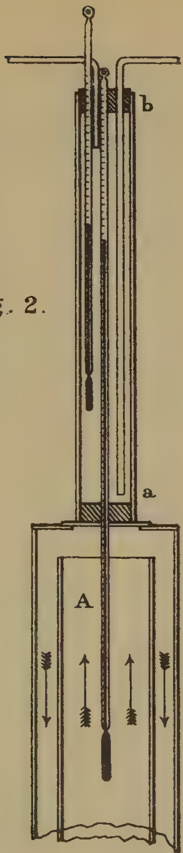
DIAGRAM Nº 3.

Aug 18th 1881.

Experiment on 3" Pure Silver Ball immersed in Fluid Silver.



Mintern Bros lith



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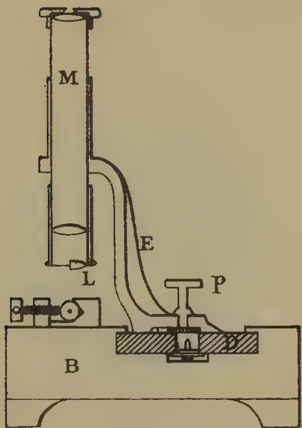

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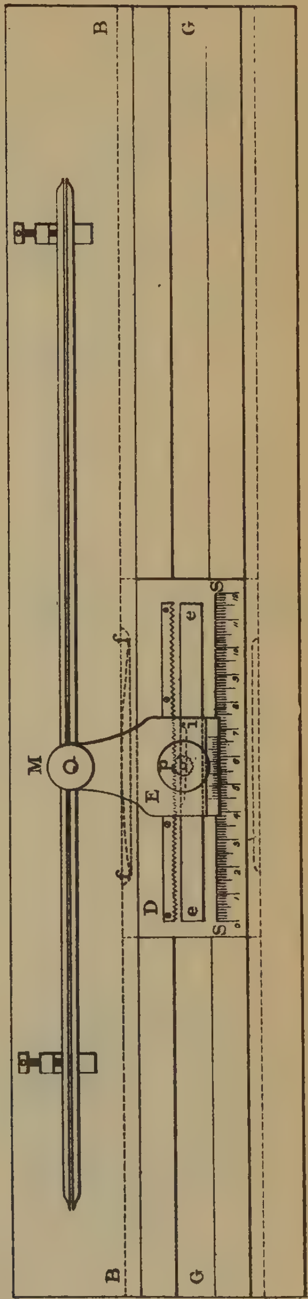
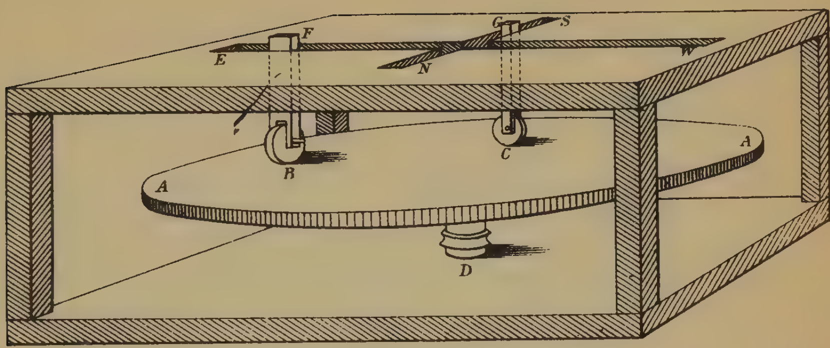


Fig. 1.

Mintern Bros. lith.



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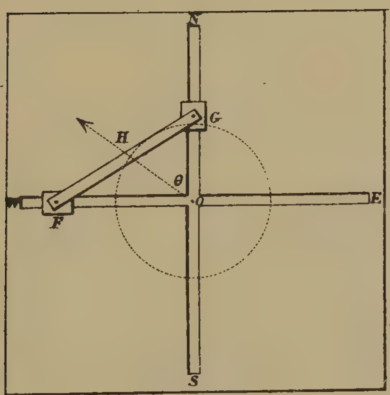

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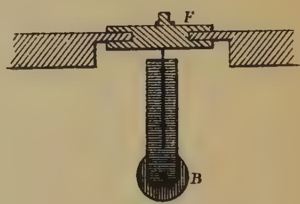

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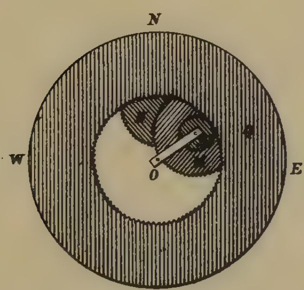

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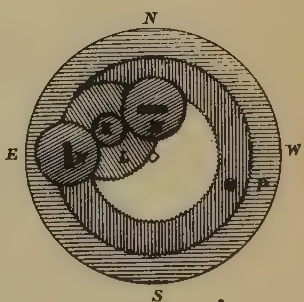

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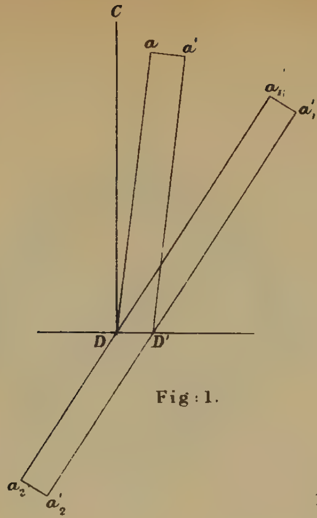
Mintern Bros lith.



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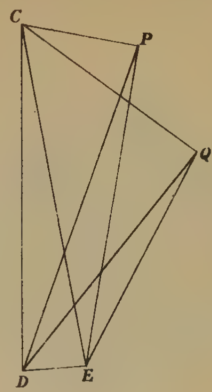

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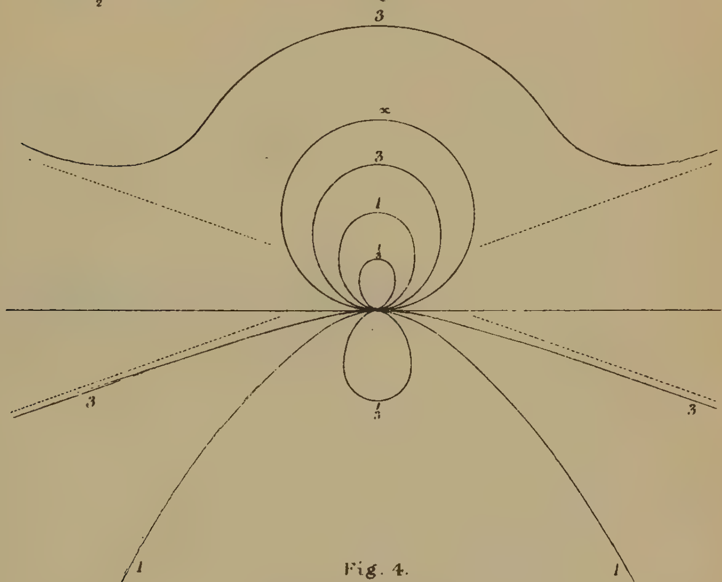

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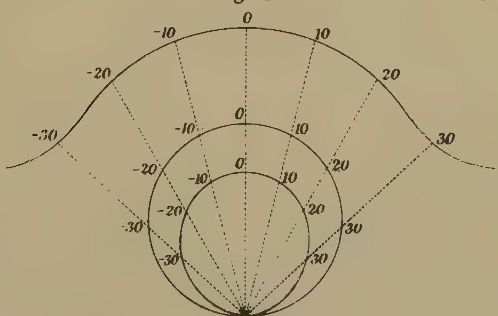

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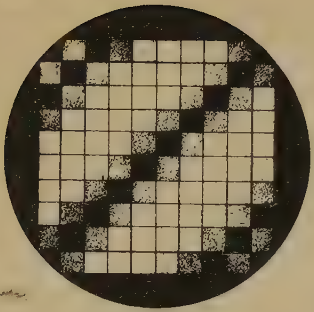

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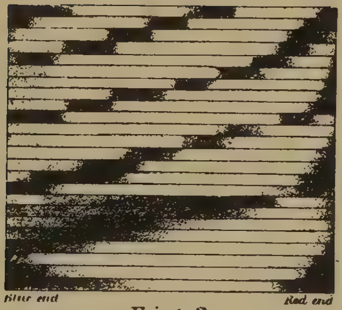

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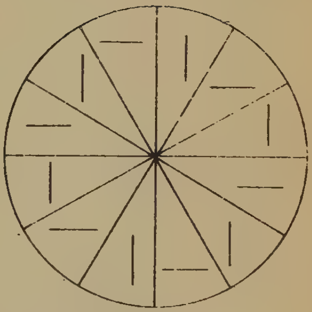

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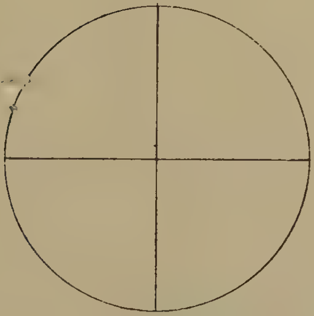
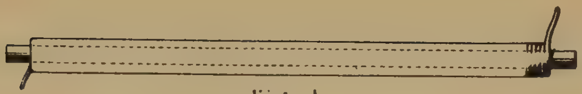


Fig. 5.

Fig. 6.

Mintern Bros lith.



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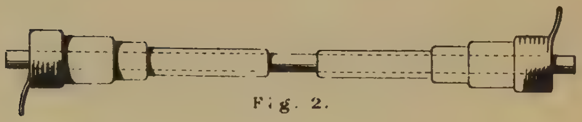

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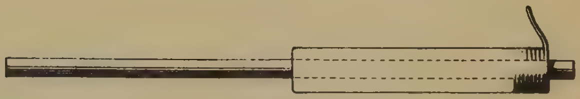

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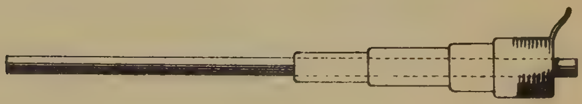


Fig. 4.

"WINDING ELECTROMAGNETS."

CURVES BETWEEN
TANGENT OF DEFLECTION OF NEEDLE AND
DISTANCE OF CORE FROM NEEDLE.

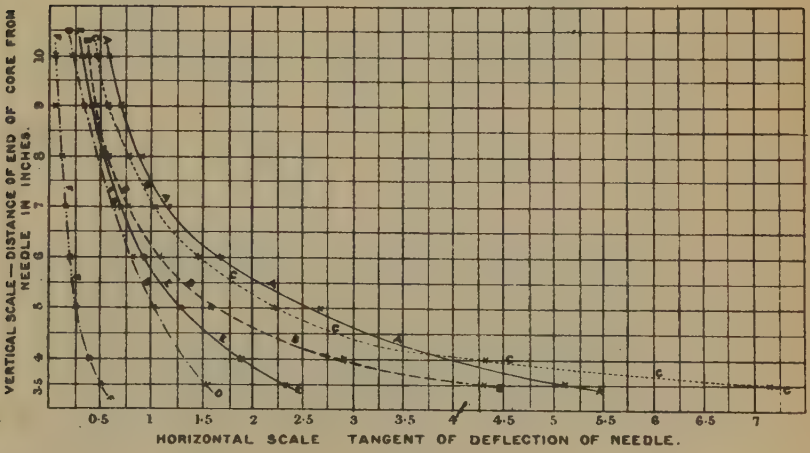
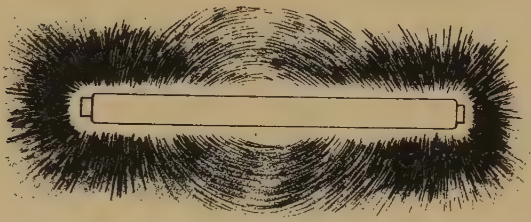


Fig. 5.

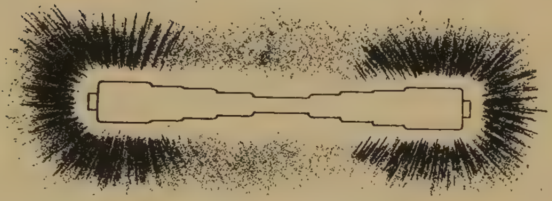
Mintern Bros lith

"WINDING ELECTROMAGNETS."

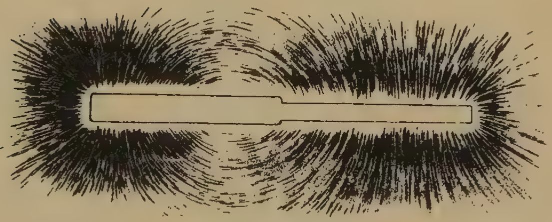
LINES OF FORCE AS SHOWN BY IRON FILINGS.



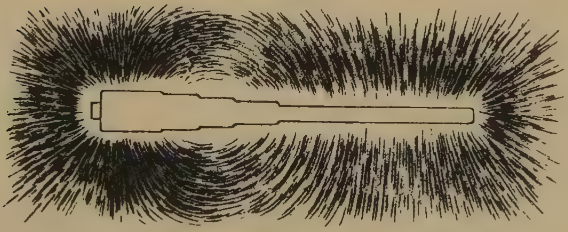
No. 6.
WOUND REGULARLY OVER WHOLE LENGTH.



No. 7.
WOUND CONED TOWARDS EACH END.



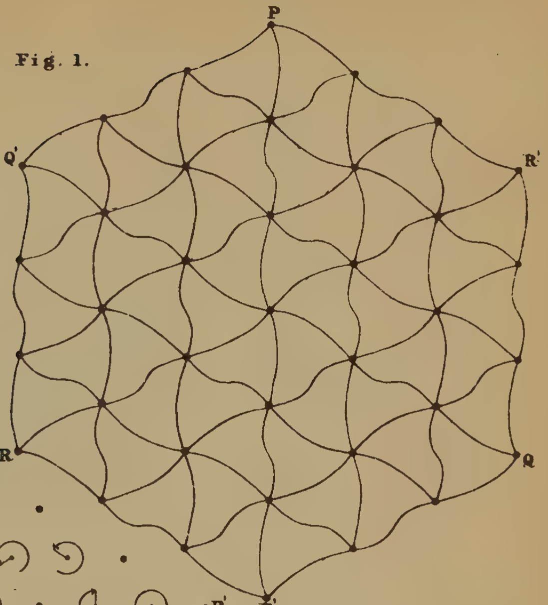
No. 8.
WOUND REGULARLY OVER HALF LENGTH.



No. 9.
WOUND CONED OVER HALF LENGTH.

Mintern Bros. lith.

Fig. 1.



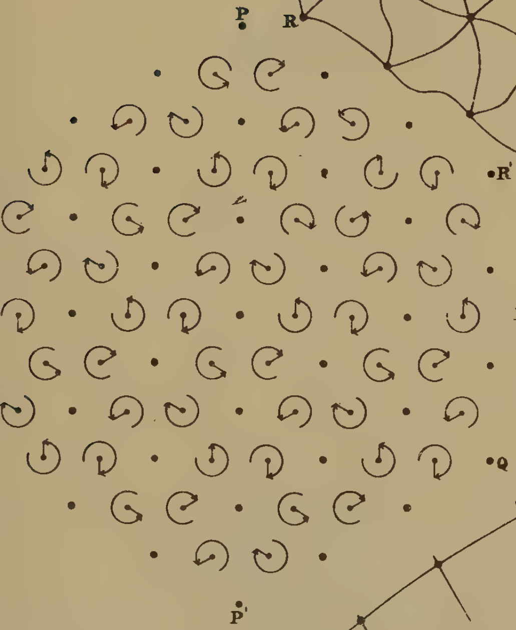


Fig. 2.

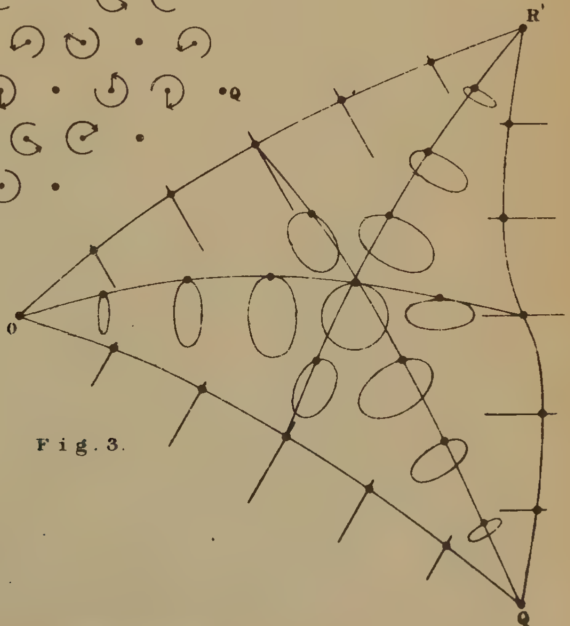


Fig. 3.

Mintern Bros lith.

Fig. 1.

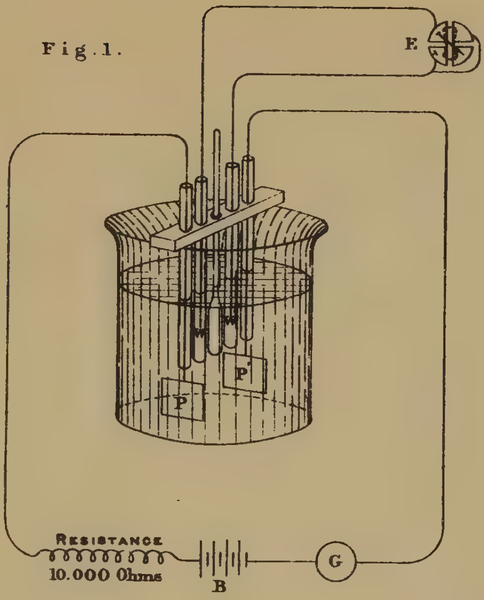
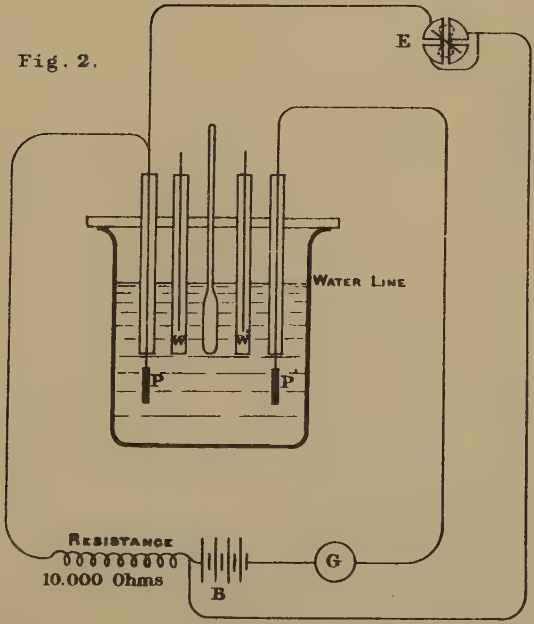


Fig. 2.



Mintern Bros. lith.

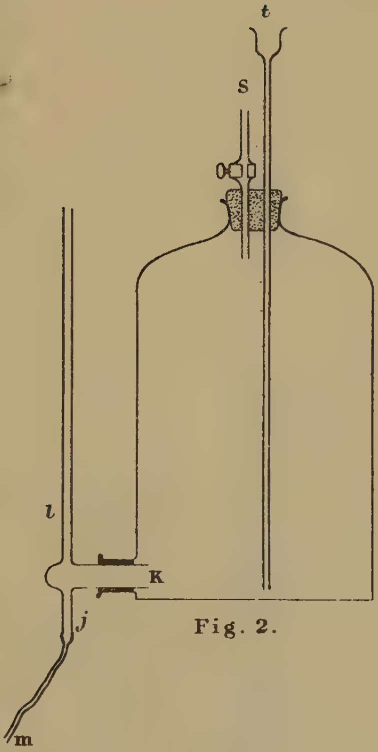


Fig. 2.

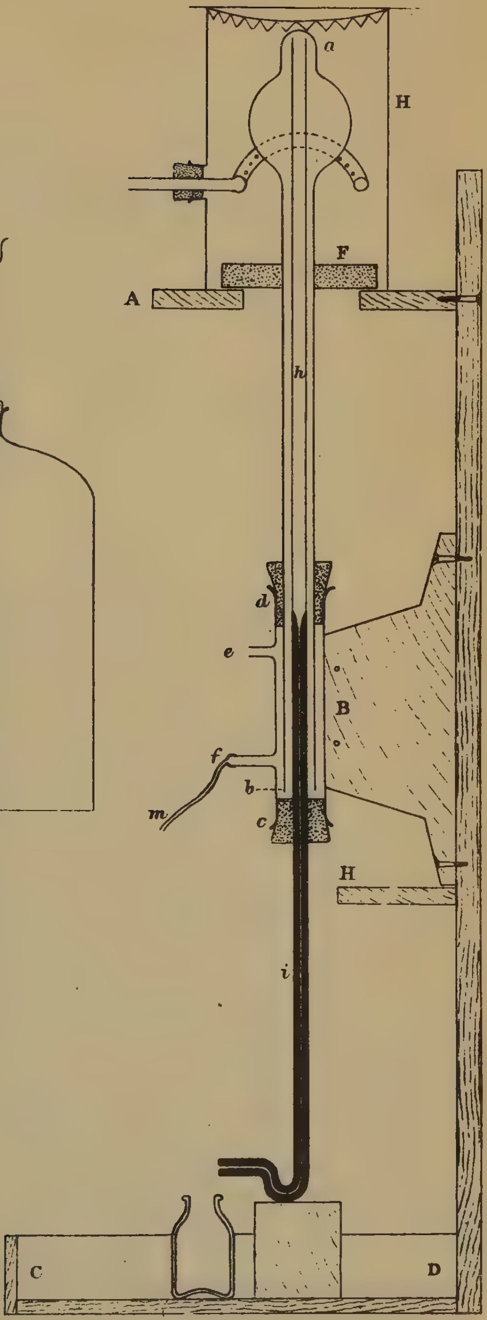


Fig. 1.

Mintern Bros. lith.

Fig. 1.

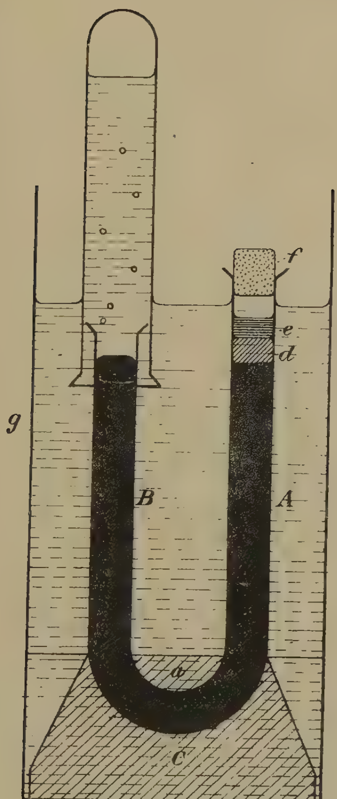


Fig. 2.

Fig. 3.

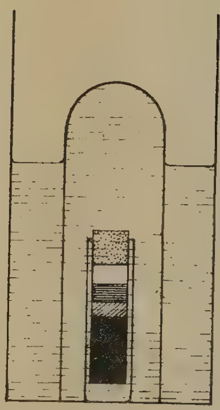


Fig. 4.

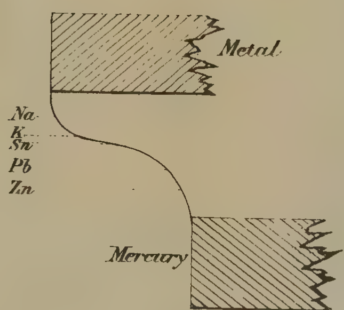
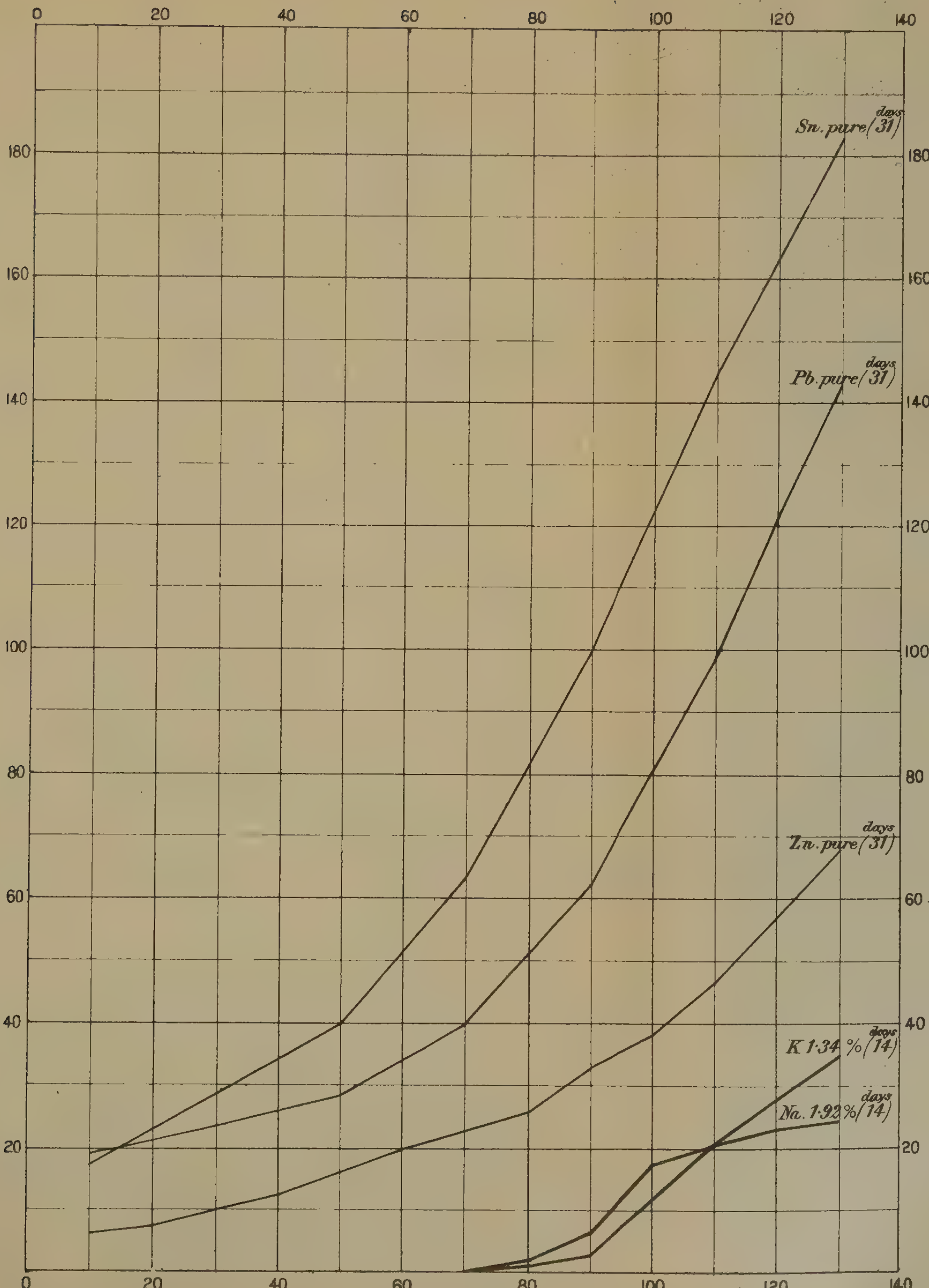


Fig. 5.


Sn. pure (31) days
Pb. pure (31) days
Zn. pure (31) days
K 1·34 % (14) days
Na. 1·92 % (14) days
0
20
40
60
80
100
120
140
160
180

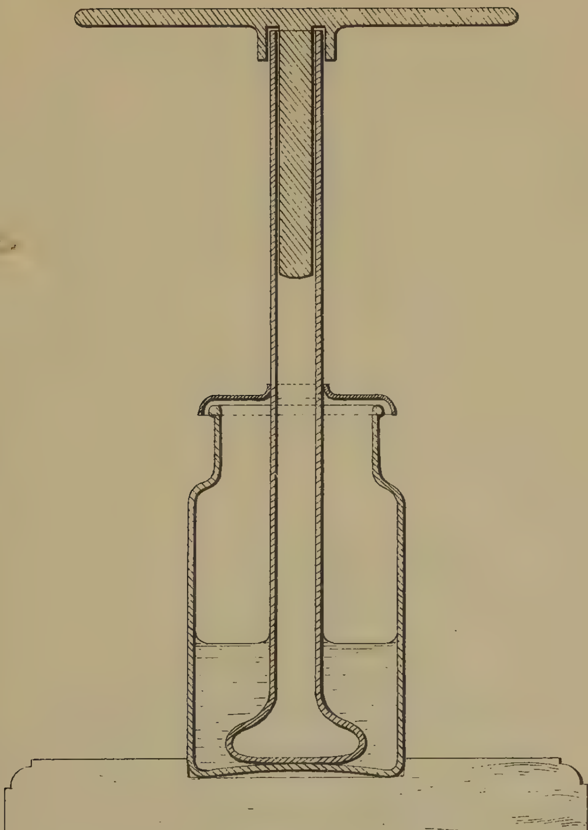


Fig. 1.

Fig. 2.

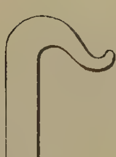


Fig. 3.

Fig. 4.

Fig. 5.

Scale ½.

Mintern Bros. lith.

PROCEEDINGS

AT THE

MEETINGS OF THE PHYSICAL SOCIETY

OF LONDON.

SESSION 1881-82.

February 12th, 1881.

Prof. W. G. Adams, M.A., F.R.S., Vice-President, in the Chair.

Annual General Meeting.

The Report of the Council was read.

The Treasurer made his financial statement.

The Officers for the Session were elected.

Special General Meeting.

Resolution passed respecting the investment of the Society's funds.

Ordinary Meeting.

The following communications were made:—

"On the Density of Fluid Bismuth." By Prof. W. Chandler Roberts and Mr. T. Wrightson.

"Hydro-mechanical Illustrations of Electrical Phenomena." By Dr. O. J. Lodge.

February 26th, 1881.

Prof. FULLER, M.A., Vice-President, in the Chair.

Special General Meeting.

Confirmation of Resolution passed at Special General Meeting held on February 12th.

Ordinary Meeting.

The following communications were made:—

"Hydro-mechanical Illustrations of Electrical Phenomena" (*continued*). By Dr. O. J. LODGE.

"On the Telegraphic Transmission of Pictures of Natural Objects." By Mr. SHELFORD BIDWELL. With experimental illustrations.

"On an Integrating Machine." By Mr. C. VERNON BOYS.

March 12th, 1881.

Sir WILLIAM THOMSON, LL.D., F.R.S., President, in the Chair.

The following were elected Members of the Society:—

COLVILE BROWNE, F.G.S.; JAMES PRESCOTT JOULE, D.C.L., F.R.S.

The following communications were made:—

"On the Absorption-Spectra of Organic Compounds." By Col. FESTING, R.E., and Capt. ABNEY, R.E., F.R.S.

"On the Definition of 'Work.'" By Mr. D. R. BROWNE.

March 26th, 1881.

Prof. FULLER, M.A., Vice-President, in the Chair.

The following was elected a Member of the Society:—

LEWIS WRIGHT.

The following communications were made:—

"Investigations in Electrostatics." By Dr. J. MOSER.

"On the Electrical Resistance of Thin Films, and on a Revision of Newton's Scale of Colours." By Profs. REINOLD and RÜCKER.

April 9th, 1881.

Prof. W. G. Adams, M.A., F.R.S., Vice-President, in the Chair.

The following was elected a Member of the Society:—

Dr. J. Moser.

The following papers were read:—

"On Thermal Electrolysis." By Dr. J. H. Gladstone and Mr. A. Tribe.

"On Radiation through Ebonite." By Col. Festing and Capt. Abney.

"On Stereoscopic Vision." By Prof. Helmholtz.

May 14th, 1881.

Prof. Fuller, M.A., Vice-President, in the Chair.

The following were elected Members of the Society:—

Mr. D. J. Blaikley; Mr. Walter Kllner, B.A., M.B.

The following papers were read:—

"On Electric Absorption in Crystals." By Prof. H. A. Rowland (Baltimore) and Mr. E. H. Nichols.

"On an Absolute Sine Electrometer." By Prof. Minchin.

"On the Ascent of Hollow Glass Bulbs through Liquids." By Dr. E. J. Mills.

May 28th, 1881.

Prof. Fuller, M.A., Vice-President, in the Chair.

The following communications were made:—

"On certain Models to illustrate Fresnel's Theory of Plane Waves." By Mr. C. J. Woodward.

"Experiments for the Determination of the Velocity of Light." By Prof. G. Forbes.

"On the Influence of a Powerful Magnet on Strips of Metal through which a Current is flowing." By Dr. E. H. Hall.

June 11th, 1881.

LORD RAYLEIGH, F.R.S., Vice-President, in the Chair.

The following were elected Members of the Society:—

J. E. STEAD; J. E. H. GORDON, M.A.

The following papers were read:—

"On Standard Resistance-Coils." By Prof. J. A. FLEMING.

"On the Hardening and Tempering of Steel." By Prof. W. C. ROBERTS.

"On Curves of Electromagnetic Induction." By W. GRANT.

"On the Opacity of Tourmaline Crystals." By Prof. S. P. THOMPSON.

June 26th, 1881.

Prof. FULLER, M.A., Vice-President, in the Chair.

The following was elected a Member of the Society:—

Señor OLYMPIO DE BARCELOS.

The following communications were made:—

"On Induction Apparatus suitable for Lecture purposes." By W. GRANT.

"On the Index of Refraction of Ebonite." By Profs. AYRTON and PERRY.

"On the Microphonic Action of Selenium-cells." By Dr. J. MOSER.

"On a Standard Cell for Electromotive Force." By Dr. J. MOSER.

"On the Repulsion of a Magnet by a moving Conductor." By Dr. F. GUTHRIE.

"Results obtained with a new Mercury Calorimeter." By Prof. BALFOUR STEWART and Mr. W. STROUD.

"On the Electromotive Force between Liquids and Metals." By Mr. SUTHERLAND.

November 12th, 1881.

Prof. FULLER, M.A., Vice-President, in the Chair.

The following was elected a Member of the Society:—

W. D NIVEN, M.A.

The following communications were made:—

"On Spirals in Crystals." By Mr. Lewis Wright.

"On a Mode of constructing Water-Pipes so as to prevent their Bursting in Frosty Weather." By Mr. C. Vernon Boys.

November 26th, 1881.

Prof. W. G. Adams, M.A., F.R.S., Vice-President, in the Chair.

Mr. C. Vernon Boys gave an account of his new Integrating-Machines.

December 10th, 1881.

Prof. W. G. Adams, M.A., F.R.S., Vice-President, in the Chair.

The following were elected Members of the Society:—

Lieut. Charles E. Gladstone, R.N.; Arthur W. Clayden, M.A.; Walter George Woollcombe, M.A.; Lieut. Charles Gauntlett Dicken, R.N.; Rev. Prof. Sebastian Sircom, M.A.

The Members visited the scientific appliances at the Smoke Abatement Exhibition, under the guidance of Prof. W. Chandler Roberts.

January 28th, 1882.

Dr. W. H. Stone in the Chair.

The following was elected a Member of the Society:—

W. Lant Carpenter, B.A., B.Sc.

The following papers were read:—

"On the Fluid Density of Metals." By Prof. W. Chandler Roberts and C. Wrightson.

"On Apparatus for measuring Efficiency." By C. Vernon Boys.

"On an Electric Meter." By T. Vernon Boys.

"On the Violet Phosphorescence in Calcium Sulphide." By Capt. Abney, R.E.

Annual General Meeting.

February 11th, 1882.

Prof. W. G. Adams, M.A., F.R.S., Vice-President, in the Chair.

The following Report of the Council was read by the Vice-President:—

Our Society now enters on the tenth year of its history; for its formation may be considered to have begun with the meeting of the Provisional Committee that followed the issue of a circular addressed by Prof. Guthrie to the leading Physicists of this country in 1873.

The success which attended its formation has been uninterrupted and progressive; and the Society now consists of 331 Members, 14 of whom were elected during the past Session.

Prof. Helmholtz was present at our Meeting in April last, and made a communication to the Society on Stereoscopic Vision.

Of the numerous papers read during the past Session, the following may be specially mentioned:—The first, a communication from America, was a paper read on May 14th, "On Electric Absorption in Crystals," by Prof. Rowland (of Baltimore) and Mr. E. H. Nichols. On the 28th of the same month, Mr. Hall (of Johns Hopkins University) read a paper "On the Influence of a Powerful Magnet on Strips of Metal through which a Current is passing," and described his investigations, which our President subsequently characterized as the most important of the year. The Society will have listened with much pleasure to the valuable series of papers by Mr. C. V. Boys on Mechanical Appliances for Integration.

The most important event of interest to the Society during the past year was the opening of the Electrical Exhibition at Paris in the autumn, and the assembling of the Congress of Electricians, at which our Society was represented by Sir William Thomson, Prof. W. Grylls Adams, and Prof. G. Carey Foster.

After an exhaustive discussion of the question of Electrical Standards, the Congress adopted the definition of electrical units recommended by the British Association, using mercury as a standard. It was, however, considered essential that fresh experiments should be made in order to ascertain the length at zero of the mercurial column, to be adopted in practice as giving a resistance of one ohm with a sufficient degree of accuracy.

The value of the work of the Congress generally was well summed up by M. Mascart, who said (in an official report addressed to the

Minister of Posts and Telegraphs):—"The International Congress, using the Exhibition as if it were a vast laboratory, has secured the greatest possible publicity for the discoveries of scientific men, and has imparted new life to the genius of inventors. Apart from its influence on technical science, the Congress has done good work that must aid the general progress of mankind, at the same time that it serves to fix an important date in the history of Electricity."

It is hoped that the forthcoming Exhibition in this country may prove of equal interest and importance.

During the past year public attention has also been directed to the abatement of smoke; and an Exhibition, now drawing to a close, has been held in the adjacent galleries belonging to the Horticultural Society. The Committee includes several members of our Society; and the work they are endeavouring to carry out is a continuation of that which occupied the attention of Parliament in the Session 1819–20, when a Select Committee was appointed to consider the effect of factory furnaces on public health, and in 1843, when another Committee inquired into the means and expediency of preventing the nuisance of smoke. As this question of the abatement of smoke is of national importance, and as the principles on which perfect combustion depends are as much within the province of Physics as of Chemistry, the Council feel that the subject is well worthy the attention of our Members.

The Committee for Re-publication have not yet been able to commence the reprint of Dr. Joule's scientific papers, of which mention was made in last year's Report. The distinguished physicist, whom we are honoured by counting among our members, has himself kindly undertaken the preparation of the copy for this work, and he has wished to get the greater part of the material ready before actually beginning to print. Dr. Joule promises to supply the first part of the copy in a very short time, in which case the printing will be at once commenced.

The prospect of a speedy beginning of this important undertaking, which will fully engage the Society's resources, has decided the Committee not for the present to begin the reprint of Volta's papers.

With regard to the important question of the protection of buildings from lightning, it will be remembered that the Society appointed Profs. Adams and Foster to represent the Society at a Conference on Lightning-Rods. This Conference has held meetings during the last three years; and after a thorough investigation of the subject, including the work done in this country and

abroad, has issued a comprehensive Report to which evidence of various experts is appended. Copies of this Report may be had by Members of this Society at a reduced price.

The Society has to regret the loss of two of its Members—Dr. DRAPER and Mr. LOUIS SCHWENDLER*.

JOHN WILLIAM DRAPER, M.D., LL.D., one of our distinguished Honorary Members, President of the Medical and Scientific Faculties of the University of New York, who died January 4, 1882, was an Englishman, having been born at St. Helens, near Liverpool, on May 5, 1811; he was therefore in his seventy-first year.

Up to the age of twenty-two he was resident in his native country, receiving his education, first under private tutors, and afterwards studied Chemistry in the University College, London, then known as the University of London. In 1832 he emigrated to the United States, and continued his studies at the University of Pennsylvania, where (in 1836) he took the degree of M.D. Meantime his talent for original research had manifested itself in the production of several memoirs, which appeared in the 'Journal' of the Franklin Institution. The first of these (published in 1834) was "On the Nature of Capillary Attraction;" while a second was devoted to a discussion of the most eligible method of constructing galvanic batteries of four elements. In 1835 he published an account of some experiments made to ascertain whether light exhibits any magnetic actions. Several branches of the science of electricity subsequently claimed his attention. In 1839 he wrote a memoir, which afterwards was reprinted in the 'Philosophical Magazine,' "On the Use of a Secondary Wire as a Measure of the Relative Tension of Electric Currents." It is instructive to observe in this memoir how Draper's exact mind revolted against the misuse, by writers on electricity, of the words "tension" and "intensity;" and though he himself employed both words, he carefully distinguished between them, using "tension" for what we now call "electromotive force," and "intensity" for the "strength of the current," agreeing, therefore, with the practice of many continental authorities. He also made experiments upon electro-capillary motions, and contributed to the science of thermo-electricity a valuable series of determinations of the thermo-electromotive force of different pairs of metals at different temperatures. In 1837 began the notable

* The following biographical sketches are mainly borrowed from 'Nature and the 'Telegraph Journal' respectively.

series of researches upon the nature of rays of light in the spectrum, with which the name of Draper will always be associated. His paper that year bore the title, "Experiments on Solar Light;" but it failed to attract much attention in Europe. He was now devoting himself to photography and photo-chemistry with great zeal. His paper "On the Discovery of Latent Light," in 1842, dealt with the images produced by rays of light which are only subsequently developed by some chemical reaction—a process with which the art of photography has made us familiar, but which was then a curious and novel phenomenon. It was Draper who first discovered that in the ultra-violet part of the spectrum there are absorption-bands like the Fraunhofer lines in the visible part of the spectrum. To enumerate the works which proceeded from Draper's pen upon the chemical and physical properties of the ultra-violet, or, as he styled them, "tithyonic" rays would be inadmissible here. Suffice it to say that the greater part of the fifty memoirs mentioned in the Royal Society's 'Catalogue' related to this subject, and the most important of them are to be found reprinted in his 'Scientific Memoirs,' published in 1878. In this volume may be found the pregnant suggestion for a standard of white light for photometry of a piece of platinum-foil, of given size and thickness, raised to a white heat by an electric current of specified strength. To guard against fusion he suggested that an automatic short-circuiting apparatus should be constructed by some "skilled artificer." He thus exactly anticipated Edison's first incandescent lamps, though the satisfactory standard of white light appears to be as far off as ever.

The latest papers Draper published were entitled "Researches in Actino-Chemistry," and treated of the distribution of heat and of chemical force in the spectrum. They appeared in 1872 in the 'American Journal of Science' and in the 'Philosophical Magazine.' During these years of work Draper held important appointments, first in the Hampden-Sidney College, Virginia, where he was Professor of Chemistry, Natural Philosophy, and Physiology; and afterwards (1839) in the University of New York, where he was Professor of Chemistry and Natural History—a post modified two years later into that of Professor of Chemistry in the Medical College of the University. In addition to the original memoirs enumerated above, Dr. Draper wrote several valued text-books of science—a text-book of Chemistry in 1846, and a Human Physiology in 1856, both of which works went through several editions.

Dr. Draper's literary activity manifested itself, however, in other

directions; and he has left an enduring mark in literature as a philosophical historian of no mean merit. The 'History of the Intellectual Development of Europe,' published in 1862, has been translated into all the current languages of European nations. His 'History of the American Civil War,' a work which appeared between the years of 1867 and 1870, when the bitter animosities of the strife were still raging, is distinguished by an impartiality of tone and a philosophical elevation remarkable in a historian, and trebly remarkable in one who wrote in times so little remote from the stirring events recorded. In 1874 Dr. Draper published a 'History of the Conflict between Science and Religion,' a work which attracted some notice, and for which a preface was written by Prof. Tyndall, to introduce the work to English readers. Though unequal to the preceding works in merit, and marred by assumptions that detract from its value, it nevertheless showed great vigour of intellect and philosophical power.

Carl Louis Schwendler.—On the 6th of January, at the village of Schoeneberg, near Berlin, after a long and painful illness, died, at the comparatively early age of forty-three, Carl Louis Schwendler, whose name will long be remembered in connexion with Indian telegraphy. He was born on the 18th of May, 1838, at Torgau, in Prussia, where his father was a captain in an infantry regiment.

Schwendler entered the Berlin Technical Academy as a student in 1856; and had then full opportunity to follow his inclinations, and to combine his technical studies with the course of the Berlin University; and thus he had some of the best teachers—Dove, Grasshoff, Rammelsberg, Weierstrass, Wiehe, Ritter. Shortly after, he happened to come in contact with Dr. Werner Siemens, who at once recognized his talent.

He was in May 1861 engaged upon experiments with the Malta-Alexandria cable. He was Chief Electrician during the manufacture and laying of several cables for the French Government, and in 1863–64 was sent to the Mediterranean to lay one of those cables.

In 1865 he, in conjunction with Mr. Sabine, contributed a short paper to the British Association meeting. The following year, in the 'Philosophical Magazine,' Schwendler published a valuable paper, "On the most suitable Galvanometer-Resistance to be employed in Testing with the Wheatstone Bridge," which subject, till then greatly neglected, he had taken great pains to investigate, both experimentally and mathematically. He retained his appointment with Siemens Brothers until 1868, when Colonel Robinson, the

Director-General of Telegraphs in India at that time, found it was necessary for him to have the aid of an experienced electrician, in order to put uniformity into the system of Government telegraphs there. Schwendler then became Assistant Electrician to the Director-General of Telegraphs in India early in 1868, and remained in that position until the commencement of 1870. Highly appreciated for his integrity, ability, and amiability by the whole staff, he was offered by his chief a commanding position in the Government service as Chief Instructor of Indian Telegraphs; and, acting under official instructions, he, soon after his arrival in India, commenced the preparation of his now well-known 'Testing Instructions,' for the guidance of the Staff of the Government Telegraph Department, the object in view being to facilitate the introduction and thorough understanding on the part of the officials of a rational system of testing.

Besides the performance of his official duties, Schwendler was busy with many collateral subjects of investigation, on some of which he contributed papers to the Asiatic Society, of which he was a Member of Council, and to the 'Philosophical Magazine.' In 1870 he investigated and published "an Arrangement for the Discharge of long Overland Telegraph-Lines," and "A practical method of locating bad Insulators in Telegraph-Lines." In 1872 he published a paper, "On the best Resistance of the Coils of any Differential Galvanometer," and another paper, "On the General Theory of Duplex Telegraphy," and one "On Earth-Currents;" and in 1876 another paper, "On Duplex Telegraphy."

In 1876 Schwendler received leave of absence, and returned to England to recruit his health. While in England, in 1877, he was elected a Member of the Council of the Society of Telegraph Engineers and of Electricians, to which he gave his assistance until he returned to India.

Early in 1877 Schwendler was requested by the Board of Directors of the East-Indian Railway Company to institute detailed inquiries into the position of electric lighting in England, with a view to the illumination of the Indian railway-stations. The series of experiments which Schwendler then carried out was an elaborate and, as far as his materials went, an exhaustive one, occupying him until November 1878. Having to return to India, he was unable to finish a complete report before his departure; but he prepared a *précis*, which was printed and issued.

In March 1879 Schwendler read a paper before the Asiatic

Society of Calcutta on the economy, practicability, and efficiency of the electric light for certain illuminating purposes, and on the best means of its distribution—the substance of his paper being, of course, based upon his experiments made in London. In the same year he published a paper on a new standard of light; and then, reverting to telegraphy, we find a paper, "On a Method of using a small Fraction of the main Current provided by a Dynamo-electric Machine for Telegraphic Purposes." This idea became a favourite one with Schwendler; and as late as last year he published a paper on "Some Experiments to supply all Lines terminating at the Calcutta Station with Currents tapped from a single Dynamo-electric Machine."

Of Schwendler's most recent life and work in India, we know very little. Some years since, we believe, he suffered from an attack brought on by the heat of the climate, which his natural vigour and robustness enabled him subsequently to disregard, if not absolutely to forget, but which possibly laid the foundation for the fatal illness which necessitated his return to Europe, and to which he at length succumbed.

He joined our Society in 1875.

The Council would again call attention to the obligation under which the Society rests to the Lords of the Committee of Council on Education for the use of the Physical Lecture-Room and Laboratories, so generously placed at its disposal; and they have again also to record their gratitude to Dr. Guthrie for his services as Demonstrator.

The Society then proceeded to the election of Council and Officers for the ensuing year; and the following gentlemen were declared duly elected:—

President.—Prof. R. B. Clifton, M.A., F.R.S.

Vice-President (who has filled the Office of President).—Sir Wm. Thomson, LL.D., F.R.S.

Vice-Presidents.—Prof. G. C. Foster, F.R.S.; Prof. F. Fuller, M.A.; J. Hopkinson, M.A., D.Sc., F.R.S.; Lord Rayleigh, M.A., F.R.S.

Secretaries.—Prof. A. W. Reinold, M.A.; Prof. W. Chandler Roberts, F.R.S.

Treasurer.—Dr. E. Atkinson.

Demonstrator.—Prof. F. Guthrie, Ph.D., F.R.S.

Other Members of Council.—Prof. W. G. Adams, M.A., F.R.S.; Prof. W. E. Ayrton, F.R.S.; Walter Baily, M.A.; Shelford Bidwell, M.A., LL.B.; W. H. M. Christie, M.A., F.R.S.; Prof. J. Fleming, D.Sc.; R. J. Lecky, F.R.A.S.; Hugo Müller, Ph.D., F.R.S.; Prof. Osborne Reynolds, M.A., F.R.S.; Prof. A. W. Rücker, M.A.

The following was elected an Honorary Member:—

Prof. G. Quincke.

After the names of the Council and Officers had been announced from the Chair, votes of thanks were passed:—to the Lords of the Committee of Council on Education; to the President; to Prof. Guthrie for his valuable services to the Society; to the Officers; and to the Auditors.

THE TREASURER IN ACCOUNT WITH THE PHYSICAL SOCIETY, FROM DECEMBER 31ST, 1880, TO DECEMBER 31ST, 1881.

Dr.	£ s. d.	£ s. d.
Balance in Bank		167 13 10
„ due by Treasurer		13 17 6
Cheque not presented		4 0 0
Entrance-Fees	16 0 0	
Subscriptions for 1879	2 0 0	
„ 1880	15 0 0	
„ 1881	125 0 0	
„ 1882	10 0 0	
Life Compositions	60 0 0	
		228 0 0
One year's Dividend on £400 4 per cent. Furness Debenture Stock, less Income Tax, 8s.		15 12 0
One year's Dividend on £460 5 per cent. Midland Preference Stock, less Income Tax, 11s.		22 9 0
One year's Dividend on £200 Metropolitan Board of Works Stock, at 3½, less Income Tax		6 17 0
Sales from Dec. 1, 1880, to Dec. 1, 1881:—		
Wheatstone	6 15 0	
Proceedings	2 0 0	
	8 15 0	
Commission	0 17 6	
		7 17 6
Due to Treasurer		15 4 0
		£481 10 10

Cr.	£ s. d.	£ s. d.
Cheque to Chapman		4 0 0
Subscription repaid		1 0 0
Library:—		
Williams and Norgate	2 19 0	
Bookbinding	8 0 0	
		10 19 0
Reports of Meetings		16 4 6
Chapman:—Attendance and Petty Cash		4 10 2
Purchase of £200 4 per cent. Lancaster Corporation Stock		214 0 0
Stationery Box		2 0 0
Stationery and Stamping		4 0 9
Messrs. Taylor and Francis:—		
Vol. iv. (4 parts), Proceedings	128 16 6	
Postage and addressing	12 11 7	
Members' separate copies	26 17 6	
Miscellaneous printing	15 9 0	
		183 14 7
Petty Cash:—		
Mr. A. W. Reinold	2 0 8	
Mr. Roberts	0 14 0	
Dr. Atkinson	2 2 10	
		4 17 6
Balance in Bank		36 4 4
		£481 10 10

Audited and found correct,

London, February 9th, 1882.

SHELFORD BIDWELL, } *Auditors.*
EDWARD RIGG,

PROPERTY ACCOUNT OF THE PHYSICAL SOCIETY.

Assets.	£	s.	d.	Liabilities.	£	s.	d.
Balance in Bank	36	4	4	Subscriptions in advance, for 1882	10	0	0
Subscriptions due for 1881 and previous years	38	0	0	Bill to Taylor and Francis	33	0	7
£400 4 per cent. Debenture Stock Furness Railway at 103	412	0	0	Due to Treasurer	15	4	0
£460 5 per cent. Midland Railway Preference Stock at 123	565	0	0	Balance	1416	19	9
£200 Metropolitan Board of Works Stock	210	0	0				
£200 Lancaster Corporation Stock	214	0	0				
	£1475	4	4		£1475	4	4

We have examined the above Account, and also the Securities at the Bank, and find the same to be correct.

London, February 9th. 1882.

SHELFORD BIDWELL,
EDWARD RIGG, } *Auditors.*

PROCEEDINGS

AT THE

MEETINGS OF THE PHYSICAL SOCIETY

OF LONDON.

SESSION 1882–83.

February 11th, 1882.

Annual General Meeting.

Prof. W. G. Adams, F.R.S., Vice-President, in the Chair.

The Report of the Council was read.

Election of President, Officers and Council, and Honorary Members.

Ordinary Meeting.

Prof. R. B. Clifton, F.R.S., President, in the Chair.

The following papers were read:—

"On the Relation between the Electromotive Force of a Daniell's Cell and the Chemical Affinities involved in its Action." By Dr. C. R. Alder Wright.

"On the Influence of the Form of Conductors on Electrical Conduction Resistance." By Dr. G. Gore.

February 25th, 1882.

Prof. G. C. Foster, F.R.S., Vice-President, in the Chair.

The following were elected Members of the Society :—

Lieut. Herbert J. Dockrell, R.N.; Charles Richardson; William Ford Stanley, F.M.S., M.R.I.; General H. Hyde, late R.E.; John Buchanan; Prof. George Francis Fitzgerald, M.A.

The following papers were read :—

"On Faure's Accumulators." By Profs. Ayrton and Perry.

"On a Modified Form of Dispersion-Photometer." By Profs. Ayrton and Perry.

"On the Electric Resistance of Carbon under Pressure." By Prof. Silvanus P. Thompson.

"On the Refractive Index and Specific Inductive Capacity of Transparent Insulating Media." By Dr. J. Hopkinson.

"On Regnault's Determination of the Specific Heat of Steam." By Mr. J. Macfarlane Gray.

March 11th, 1882.

Prof. Fuller, M.A., Vice-President, in the Chair.

The following Members were admitted by the Chairman :—

Lieut. Herbert J. Dockrell, R.N.; Mr. Charles Richardson; Mr. William Ford Stanley.

The following was elected a Member of the Society :—

David Rhys Jones.

The following papers were read :—

"On the Influence of Dust and Sulphurous Acid on the Formation of Fog." By Mr. Newth.

"On the Discharge of Electricity by Heat." By Dr. Guthrie.

March 25th, 1882.

Prof. R. B. Clifton, F.R.S., President, in the Chair.

The following Members were admitted by the President :—

Mr. W. Lant Carpenter; Prof. G. F. Fitzgerald.

The following were elected Members of the Society:—

M. J. JACKSON, B.A., B.Sc.; LAZARUS FLETCHER, M.A.

The following papers were read:—

"On the Influence of Temperature on the Electrical Resistance of Mixtures of Sulphur and Carbon." By Mr. SHELFORD BIDWELL.

"On the Measurement of Curvature and Refractive Index." By Mr. C. VERNON BOYS.

"On the Electromagnetic Effects due to the Motion of the Earth." By Prof. G. F. FITZGERALD.

April 22nd, 1882.

Prof. R. B. CLIFTON, F.R.S., President, in the Chair.

The following Members were admitted by the President:—

Mr. M. J. JACKSON; Mr. J. BUCHANAN; Dr. EUGEN OBACH.

The following was elected a Member of the Society:—

Dr. EDWARD HOPKINSON.

The following papers were read:—

"On the Evidence of a Flowing Liquid moving by Rolling Contact upon the Interior Surface of a Pipe." By Mr. WILLIAM FORD STANLEY.

"Preliminary Notice on the Magnetic Disturbances of the Present Week." By Mr. G. M. WHIPPLE.

May 6th, 1882.

Prof. R. B. CLIFTON, F.R.S., President, in the Chair.

The following Member was admitted by the President:—

LAZARUS FLETCHER, M.A.

The following was elected a Member of the Society:—

WILLIAM HASLAM HEATON, B.A.

The following papers were read:—

"On the Construction of Bennet's Galvanic Cell." By Mr. R. J. LECKY.

"On the Mercurial Thermometer." By Mr. F. D. Brown.

"On an Experiment showing the Repulsion between a Moving Conductor and a Magnet." By Dr. F. Guthrie.

May 20th, 1882.

Prof. Fuller, M.A., Vice-President, in the Chair.

The following papers were read :—

"On the Behaviour of Powders under Pressure." By Prof. W. Chandler Roberts.

"On the Mathematical Explanation of Dr. Guthrie's Experiment showing the Repulsion between a Magnet and a Moving Conductor." By Mr. Walter Baily.

"On an Improved Current Meter." By Mr. C. Vernon Boys.

June 10th, 1882.

Prof. R. B. Clifton, F.R.S., President, in the Chair.

The following was elected a Member of the Society :—

Major-General C. N. Martin, R.E.

The following papers were read :—

"Experiments on the Vibrations of Tuning-Forks." By Mr. William Ford Stanley.

"On an Integrating Anemometer." By Mr. Walter Baily.

June 17th, 1882.

Meeting in the Clarendon Laboratory, Oxford.

Prof. R. B. Clifton, F.R.S., President, in the Chair.

The following was elected a Member of the Society :—

Prof. W. J. Lewis, M.A. Cambridge.

The following papers were read :—

"On a Simple Electrodynamometer." By Dr. W. H. Stone.

"On a Magnetic Lever for Acting on the Keys of an Organ at a Distance." By Mr. R. H. M. Bosanquet.

"On the Action of an Electrometer-Key." By the President.

"On a Reflecting Galvanometer for Lecture-purposes, which can be used either as a Sine or Tangent Galvanometer." By the President.

"On Reversing and Contact Keys for Galvanic Currents." By the President.

"On a Simple Form of Optical Bench for Measuring the Focal Length and Curvature of Lenses and Mirrors." By the President.

June 24th, 1882.

Prof. R. B. Clifton, F.R.S., President, in the Chair.

The following Members were admitted by the President:—

Mr. Rhys Jones; Major-General C. N. Martin; Mr. Coutts Trotter; Dr. E. Hopkinson.

The following were elected Members of the Society:—

Prof. Bartholomew Price, M.A., F.R.S.; Prof. John Viriamu Jones, M.A.

The following papers were read:—

"Experiments on Vibration." By Prof. Bjerknes, of Christiania.

"On the Determination of Chemical Affinity in terms of Electromotive Force."—Part VI. By Dr. C. R. Alder Wright.

November 11th, 1882.

Prof. R. B. Clifton, F.R.S., President, in the Chair.

The following Members were admitted into the Society by the President:—

Prof. J. C. Adams; Prof. H. A. Rowland.

The following papers were read:—

"On the Theory and Construction of Curved Optical Gratings." By Prof. H. A. Rowland.

"On the Conservation of Energy and the Theory of Central Forces." By W. R. Browne, M.A.

"Historical Notes on Physics." By Prof. S. P. THOMPSON.

(1) On the Original Production of the Electric Light.

(2) On the Boiling of Water under Reduced Pressure.

(3) On the Early History of the Telephone.

November 25th, 1882.

Prof. R. B. CLIFTON, President, in the Chair.

The following papers were read:—

"On Rainbows formed by Light reflected before entering the Rain-drops." By Mr. W. ACKROYD.

"On the Electrical Resistance of Selenium-cells." By Mr. SHELFORD BIDWELL.

"On a General Method of Strengthening Telephonic Currents." By Dr. J. MOSER.

December 9th, 1882.

Prof. R. B. CLIFTON, President, in the Chair.

The following were elected Members of the Society:—

HUGH ERAT HARRISON, B.Sc.; S. T. SAUNDERS, M.A.

The following papers were read:—

"On the Velocity of Light of Different Colours." By Prof. G. FORBES.

"On the Relations between the Distance apart of the Carbons in a Voltaic Arc, the Strength of the Current producing it, and the Opposition to the Current due to the Arc." By Profs. AYRTON and PERRY.

"On the Intensities of the Magnetic Field due to Electro-magnets in which the Distribution of the Wire was Variable." By Profs. AYRTON and PERRY.

Exhibition of twenty Swan Lamps, rendered incandescent by three Faure Accumulators.

January 27th, 1883.

Prof. R. B. CLIFTON, President, in the Chair.

The following Member was admitted by the President:—

Mr. H. E. HARRISON.

The following papers were read:—

"On the Methods which have been employed for Measuring Electrical Resistance in Absolute Units, with details of a Method proposed by himself." By Prof. G. CAREY FOSTER.

"On the Locus of the Spectra formed by Curved Gratings." By Mr. WALTER BAILY.

Annual General Meeting.

February 10th, 1883.

Prof. W. G. ADAMS, M.A., F.R.S., Vice-President, in the Chair.

The following Report of the Council was read by the Vice-President:—

A retrospect of the proceedings of the Society during each succeeding year has been given in the successive Annual Reports.

In the present year a more comprehensive view may fairly be taken, as this Annual Meeting completes the first decade of our history. It is true that the first Meeting of the Society was not held until the 21st of March 1874, and, further, that the Society can only date its legal existence from 1876, the year in which it was formally registered in accordance with the provisions of the 23rd Sect. of the Public Companies Act 1862; but its formation as a Society may be considered to have begun with the meeting of its Provisional Committee in 1873.

Its history has been that of Physical Science generally in the United Kingdom for the past ten years, for almost every physicist of eminence has either joined our ranks or has communicated a paper to our Meetings.

We have established an enduring bond of union with our fellow workers abroad; and the list of our Foreign Honorary Members,

which the Council will probably seek powers to extend, is sufficient to indicate the comprehensive and representative character of our organization.

The Council had hoped to be able to report that death had dealt gently with the Members of our Society, and that during the past year no one had dropped from our ranks; but yesterday one of our most distinguished Members, who only a few days ago was employing his extraordinary intellectual powers for the advancement of various branches of science, passed from among us, and we, in common with many other Societies, have to mourn an irreparable loss.

Henry John Stephen Smith, Savilian Professor of Geometry in the University of Oxford, died at Oxford on the 9th of February, at the age of fifty-six.

Ever since his admission to the University as Scholar of Balliol College, the remarkable powers of Henry Smith, both in literature and science, have been conspicuous. His Undergraduate career, brilliant almost without a parallel, was followed by a life of unceasing activity, in which his marvellously varied attainments, combined with his great capacity for business and his unflagging energy, excited the admiration of all whose good fortune it was to work with him; while his genial manners and his many social gifts endeared him to a constantly increasing circle of friends, from which, it may safely be said, no one who was once admitted ever retired.

Henry Smith was born in Dublin; but he has lived in England since the death of his father, which occurred when he was only two years old; and he was educated first at home and afterwards at Rugby.

In 1848 he gained the Ireland Scholarship founded "for the promotion of Classical learning and taste." In 1849 he passed the examination for the degree of B.A., being placed in the first class both "in Literis Humanioribus" and "in Disciplinis Mathematicis et Physicis." In 1851 he won the Senior Mathematical Scholarship; and he had thus obtained the highest distinctions which the University of Oxford has to confer both for Classics and Mathematics. He speedily became Fellow of Balliol College, and undertook the office of Mathematical Tutor in his College; an office which he retained until a few years ago, when he exchanged his Fellowship in Balliol for one in Corpus Christi College.

In 1861 he was elected to the Savilian Professorship of Geometry

rendered vacant by the death of Professor Baden Powell; and in 1874 he succeeded Professor Phillips as Keeper of the University Museum. Both these appointments he held up to the time of his death.

For many years he was a Member of the Hebdomadal Council of the University, and took a prominent part in the management of University business; while at the same time the citizens of Oxford always found him ready to assist in any movement for the promotion of their welfare or for the advancement of their educational institutions.

Lavishly as Professor Smith spent his time in the service of the University and city, his energy enabled him to discharge other most important and responsible duties. He was a Member of the Royal Commission on Scientific Education, and recently of the Commission, appointed under the Universities of Oxford and Cambridge Act 1877, charged with the task of making new statutes for the University and Colleges of Oxford. By these statutes the relations between the University and the Colleges have been considerably modified, and an attempt has been made to bring the constitution of both more into harmony with the requirements of the time; but he only lived to see the commencement of this great change; and the loss of his calm judgment and his guiding hand during the transition period makes his early death the more to be deplored.

Professor Smith was an active Member of the Royal Society, of the Royal Astronomical Society, of the London Mathematical Society (of which he was recently the President), and of the British Association for the Advancement of Science; he was also chosen in 1880 as a Corresponding Member of the Academy of Sciences in Berlin.

When the Government decided to place under the control of a Special Council the management of the Meteorological Office, and the organization of arrangements for collecting and utilizing meteorological observations, Professor Smith was selected as Chairman of this Council; and he carried on this onerous and responsible work to the last, in spite of an accumulation of other labours which would have completely overwhelmed most men, even if endowed with unusual powers of endurance.

It might seem that in the discharge of the duties already noticed the time of a busy life would be completely accounted for; but the principal work of Professor Smith has been scarcely mentioned. Before and above all he was a Mathematician. In Mathematics centred his strongest interests, to this study he devoted whatever

time he could snatch from his other occupations, and by his investigations in various branches of this subject he will be known to posterity, when the remembrance of his other labours has faded away.

His attention was specially directed to Pure Geometry, to the Theory of Elliptic Functions, and to the Theory of Numbers. On the first of these subjects he published little; but his admirable lectures have instructed many successive generations of Oxford students, and have had a marked influence on the study of Geometry in that University. Sad as it is that he was prevented from carrying out his intention of arranging these lectures for publication, it is to be hoped that they may not be entirely lost; his own notes, combined with those taken by his pupils, may yet furnish materials for a most valuable work.

On the Theory of Elliptic Functions and allied subjects several papers, published for the most part in the Transactions of English and foreign scientific Societies, bear ample testimony to Professor Smith's great power of dealing with different and refined analytical problems, and suffice by themselves to place him in the first rank of contemporary Mathematicians. But probably his fame will rest mainly upon his contributions to his favourite subject—the Theory of Numbers. His Reports (unfortunately incomplete) to the British Association on the Theory of Numbers, though professedly only an account of knowledge already acquired, are full of original matter, and the manner in which he has connected the work of his predecessors by his own methods will be an enduring memorial of his extensive knowledge, his mathematical genius, and his admirably finished style. These Reports, combined with communications to the Royal Society, the French Academy, and other Societies, will assuredly secure for Professor Smith a most prominent place among the writers on the Theory of Numbers, and cause him to be associated with Gauss, Lejeune-Dirichlet, Jacobi, Legendre, and Cauchy.

Early in his career Professor Smith gave some attention to Experimental Science, and, although other studies drew him away from active work in the domain of Physics, he always took the greatest interest in the progress of that subject, and he used his powerful influence in promoting the study of it in Oxford. To his ever ready cooperation and his wise counsel whatever success has attended the development of the department of Physics in the University may be largely ascribed.

The study of Mathematics is so absorbing to those engaged in extending its boundaries, that they are frequently led to seek retire-

ment and to stand aloof from the movements taking place in the society in which they live. This, however, was not the case with Professor Smith; for him all social and political questions had the greatest attraction, and, when in 1878 a vacancy occurred in the representation of the University in Parliament, he allowed himself to be nominated as successor to Mr. Gathorne Hardy, who had been raised to the Peerage. His supporters, however, though neither few nor undistinguished, formed but a forlorn hope: the struggle ended in their complete defeat; and thus the University of Oxford threw away the chance of being represented by the most gifted of her sons, and the country lost the opportunity of profiting by his keen intellect, his wide knowledge, and his persuasive eloquence.

The Society now consists of 340 Members, 19 of whom were elected during the present year. During the past ten years about 330 communications have been made to our Meetings, the distinctive feature of which has been the abundant and elaborate experimental illustrations that have, in nearly all cases, accompanied the reading of the papers. This we mainly owe to the care of our Demonstrator, Dr. Guthrie, whose watchfulness over our interests has been unceasing since the time his efforts resulted in our formation as a Society.

Our Financial affairs, so ably managed by Dr. Atkinson, who has been Treasurer since the formation of our Society, are in a thoroughly satisfactory condition; and the Accounts show that we possess neither the poverty that would cripple our usefulness, nor riches which might tend to make us rely less than has hitherto been the case on the individual efforts of our Members.

The keynote struck by Mr. Fleming in the new Contact Theory of the Galvanic Cell, the first paper read to our Society, has been well maintained, as no less than one third of our papers during the past ten years have been on subjects connected with electricity.

The determination of the Ohm in relation to the British-Association Unit has been actively carried on by several of our Members—Prof. G. C. Foster, Lord Rayleigh, Mr. Glazebrook, and Professor Rowland. It will be remembered that the Electrical Congress that met in Paris in 1881 decided to retain the Mercury Standard for reproduction and comparison, and, while adopting the absolute system of the British Association, referred the final determination of the unit measure of resistance to an International Committee which met in Paris in 1882.

The more remarkable contributions to the Society during the past year consisted of discourses by Prof. Bjerknes, of Christiania, and Prof. Rowland, of Baltimore. Prof. Bjerknes (who has devoted twenty-five years to tracing analogies between hydrodynamical phenomena and those of electricity and magnetism) illustrated the static attraction and repulsion of electricity and magnetism; as well as electrodynamic attractions and repulsions. The Members will remember that he employed small tambours, pulsating near each other in water or other media, to which the vibrations were imparted; the more novel effects consisting in representations of the mutual action of two electric currents flowing in the same direction. The experiments were of remarkable beauty.

Prof. Rowland exhibited on November 17 a number of his new and beautiful concave gratings, which consist of slabs of speculum metal ruled with lines varying from 5000 to 42,000 to the inch; one result of Prof. Rowland's investigation with these instruments being the division of certain lines of the spectrum that have not hitherto been separated.

Mr. W. Chandler Roberts, finding that his official duties render it impossible for him to devote the necessary time to the service of our Society, retires from the Secretaryship he has held since 1874. The announcement of his retirement has been received with general regret; but the Council felt that, considering Prof. Roberts's recently increased engagements, they could not fairly urge him to retain his post.

They are fortunate in having secured as his successor Mr. Walter Baily, who is already favourably known to our Members by his communications to our Proceedings.

It has been suggested that notices of the titles of papers to be read at our Meetings should be sent to each Member of the Society; and the Council, anxious at all times to carry out the expressed wishes of the Members, has arranged that all who desire to have such notices shall receive them gratuitously on application to Messrs. Taylor and Francis at the beginning of each Session.

With regard to the publications of the Society other than the 'Proceedings,' the Council have to report that the works of Dr. Joule are in print with the exception of about 100 pages, which the author has promised to furnish very shortly; and the Council confidently expect that the volume will be issued early in the present year. The translation and reprinting of Volta's works will remain in abeyance until the completion of Dr. Joule's volume.

The Council has also under consideration the publication of a Memoir of Dr. Gilbert, Physician to Queen Elizabeth. The accuracy and importance of his chemical and physical work has not hitherto been generally recognized; and as the Memoir will be written by Prof. Ferguson, of Glasgow, whose eminence as an historian of science is well known, it cannot fail to be of interest and value.

The Librarian reports that the Library continues to be in a very satisfactory condition; and the Council will shortly be asked to vote the sum necessary to defray the cost of binding the periodicals. Further efforts would, however, appear to be needed in order to effect an interchange of our publications with those of other Societies and Institutions.

The Society then proceeded to the election of Officers and Council for the ensuing year; and the following were declared duly elected:—

President.—Prof. R. B. Clifton, M.A., F.R.S.

Vice-President (who has filled the Office of President).—Sir Wm. Thomson, LL.D., F.R.S.

Vice-Presidents.—Prof. G. C. Foster, F.R.S.; J. Hopkinson, M.A., D.Sc., F.R.S.: Lord Rayleigh, M.A., F.R.S.; Prof. W. Chandler Roberts, F.R.S.

Secretaries.—Prof. A. W. Reinold, M.A.; Walter Baily, M.A.

Treasurer.—Dr. E. Atkinson.

Demonstrator.—Prof. F. Guthrie, Ph.D., F.R.S.

Other Members of Council.—Prof. W. G. Adams, M.A., F.R.S.; Prof. W. E. Ayrton, F.R.S.; Shelford Bidwell, M.A., LL.B.; W. H. M. Christie, M.A., F.R.S.; Prof. F. Fuller, M.A.; R. T. Glazebrook, M.A., F.R.S.; R. J. Lecky, F.R.A.S.; Prof. O. J. Lodge, D.Sc.; Hugo Müller, Ph.D., F.R.S.; Prof. J. Perry.

The following was elected an Honorary Member:—
Prof. Ludwig Boltzmann.

After the names of the Council and Officers had been announced from the Chair, votes of thanks were passed:—to the Lords of the Committee of Council on Education; to the President; to the other Officers; and to the Auditors.

The Treasurer in Account with the Physical Society, from December 31st, 1881, to December 31st, 1882.

Dr.	£	s.	d.	£	s.	d.
Balance in Bank				36	4	4
19 Entrance-Fees	19	0	0			
Subscriptions for 1879	3	0	0			
" 1880	10	0	0			
" 1881	17	0	0			
" 1882	121	0	0			
" 1883	2	0	0			
Life Compositions	100	0	0			
				272	0	0
One year's Dividend on £400 Furness 4 per cent. Debenture Stock, less Income Tax	15	13	4			
One year's Dividend on £460 5 per cent. Midland Preference Stock, less Income Tax	22	10	5			
One year's Dividend on £200 3½ per cent. Metropolitan Board of Works Stock, less Income Tax	6	16	10			
One year's Dividend on £200 Lancaster Corporation Stock, less Income Tax	7	16	8			
				52	17	3
Sales to November 30, 1882:—						
Wheatstone	3	18	9			
Proceedings	3	4	0			
	7	2	9			
Commission	0	14	3			
				6	8	6
				£367	10	1

Cr.	£	s.	d.	£	s.	d.
By Subscription repaid				1	0	0
Balance due to Treasurer, Dec. 31, 1882				15	4	0
Taylor and Francis:—						
Proceedings, vol. iv. (3 parts), vol. v. (parts 1 & 2) ...	88	12	0			
Postage and addressing	8	17	0			
Members' separate copies	15	18	0			
Miscellaneous printing	16	16	4			
Wheatstone	0	15	10			
				130	19	2
Reports of Meetings				10	0	0
Mertens:—Custom-House expenses for Prof. Bjerknes' Apparatus				5	5	0
Williams and Norgate:—Periodicals				4	0	0
Chapman:—Attendance and Petty Cash				4	6	10
Richardson:—Stationery and Printing				1	10	6
Petty Cash:—						
Mr. Reinold	1	19	8			
Mr. Roberts	0	15	2			
Mr. Atkinson	2	0	4			
				4	15	2
Clarke				0	18	0
Balance in Bank				138	0	9
" hands of Treasurer				51	10	8
				£367	10	1

Audited and found correct,

London, February 9th, 1883.

E. W. JONES,
F. W. BAYLY, } *Auditors.*

PROPERTY ACCOUNT OF THE PHYSICAL SOCIETY.

Assets.	£	s.	d.	Liabilities.	£	s.	d
Balance in Bank	138	0	9	Subscriptions in advance, for 1883	2	0	0
,, hands of Treasurer	51	10	8				
Estimated Subscriptions due	35	0	0				
£400 Furness 4 per cent. Debenture Stock	412	0	0				
£460 Midland 5 per cent. Preference Stock	565	0	0	Balance	1623	11	5
£200 Metropolitan Stock	210	0	0				
£214 Lancaster Corporation Stock	214	0	0				
	£1625	11	5		£1625	11	5

We have examined the above Account, and also the Securities at the Bank, and find the same to be correct.

London, February 9th, 1883.

E. W. JONES,
F. W. BAYLY, } *Auditors.*

PROCEEDINGS

AT THE

MEETINGS OF THE PHYSICAL SOCIETY

OF LONDON.

SESSION 1883–84.

February 10th, 1883.

Prof. FULLER, Vice-President, in the Chair.

Annual General Meeting.

The Report of the Council was read.
The Treasurer made his Financial Statement.
The Officers for the Session were elected.

Ordinary Meeting.

The following communication was made:—

"On a Graphic Method of Measuring the Efficiency of an Electric Motor." By Prof. S. P. THOMPSON.

February 24th, 1883.

Prof. Clifton, President, in the Chair.

The following were elected Members of the Society :—

Prof. A. W. Scott, M.A.; F. J. M. Page, B.Sc.

The following communications were made :—

"On Optical Combinations of Crystalline Films." By Lewis Wright.

"Experimental Demonstration of the Vortical Theory of the Solar System." By Philip Braham.

March 10th, 1883.

Prof. G. C. Foster, Vice-President, in the Chair.

The following was elected a Member of the Society :—

Major W. S. Boileau, R.E.

The following communications were made :—

"On a Method of Measuring Electrical Resistances with a Constant Current." By Shelford Bidwell.

"On certain Molecular Constants." By Dr. Guthrie.

April 14th, 1883.

Prof. G. C. Foster, Vice-President, in the Chair.

The following were elected Members of the Society :—

William Frederick Smith; George Forbes, M.A., F.R.S.E.

The following communications were made :—

"On Science Demonstration in Board Schools." By W. Lant Carpenter.

"On a Polarizing Prism." By R. T. Glazebrook.

"On Curved Diffraction Gratings." By R. T. Glazebrook.

"On the Viscosity of a Solution of Saponine." By W. H. Stables and A. E. Wilson.

April 23rd, 1883.

Prof. CLIFTON, President, in the Chair.

The following communications were made:—

"On Colour Sensations." By H. R. DROOP.

"On a New Photometer." By Sir JOHN CONROY.

"On the Causes and Consequences of Glacier Motion." By W. R. BROWNE.

"On a New Spectrometer." By the PRESIDENT.

May 12th, 1883.

Prof. CLIFTON, President, in the Chair.

The following was elected a Member of the Society:—

ALFRED WALKER SOWARD.

The following communications were made:—

"On an Experiment illustrating Motion produced by Diffusion." By C. J. WOODWARD.

"Some Uses of a New Projection-Lantern." By W. LANT CARPENTER.

"On the Determination of Chemical Affinity in terms of Electromotive Force.—Part VII. On the E.M.F. of Clark's Mercurous Sulphate Cell." By Dr. C. N. ALDER WRIGHT and C. THOMPSON.

"On the Complete Determination of a Double Convex Lens by Measurements on the Optical Bench." By the PRESIDENT.

May 26th, 1883.

Prof. CLIFTON, President, in the Chair.

The following communications were made:—

"On the Graphical Representation of Musical Intervals." By G. GRIFFITH.

"On a Phenomenon of Molecular Radiation in Incandescent Lamps." By J. A. FLEMING.

"On the Crossing of Rays." By WALTER BAILY.

"On a Modified Form of Electric Insulator." By the PRESIDENT

June 9th, 1883.

Prof. CLIFTON, President, in the Chair.

The following communications were made:—

"On an Improved Construction of the Movable Coil Galvanometer for Determining Current and E.M.F. in Absolute Measure." By Dr. E. OBACH.

"On the Electric Resistance of Water." By Profs. W. E. AYRTON and J. PERRY.

"On Apparatus for Experiments on Centrifugal Force." By Profs. W. E. AYRTON and J. PERRY.

"On Measuring the Moment of Inertia of a Fly-wheel." By Profs. W. E. AYRTON and J. PERRY.

June 23rd, 1883.

Prof. CLIFTON, President, in the Chair.

The following was elected a Member of the Society:—

C. H. STEARN.

The following communications were made:—

"On the Cause of Evident Magnetism and Neutrality in Iron and Steel." By Prof. D. E. HUGHES.

"On the Sine Electrometer." By Prof. G. MINCHIN.

"On the Electric Conductivity and other Properties of the Copper-Antimony Alloys." By G. KAMENSKY.

November 10th, 1883.

Prof. CLIFTON, President, in the Chair.

The following communications were made:—

"On the Velocity of Sound in Tubes of Various Diameters." By D. J. BLAIKLEY.

"On the Moment of a Compound Magnet." By R. H. M. BOSANQUET.

"On the Electrical Resistance of the Skin, and on certain Medico-Electrical Appliances." By W. LANT CARPENTER.

November 24th, 1883.

Prof. CLIFTON, President, in the Chair.

The following communications were made:—

"On the Purification of Mercury by Distillation *in vacuo*. By J. W. CLARK.

"On a Method of Determining the Constant of an Electro-dynamometer." By A. P. SHATTOCK.

"On the Measurement of the Curvature of Lenses, and the Refractive Indices of Liquids by means of Newton's Rings." By the PRESIDENT.

December 8th, 1883.

Prof. G. C. FOSTER, Vice-President, in the Chair.

The following were elected Members of the Society:—

WALTER G. GREGORY, B.A.; Major C. A. MACGREGOR, R.E.; JAMES WALKER, M.A.

The following communications were made:—

"On Dolbear's Static (Condenser) Telephone, and its Use in an Apparatus analogous to Wheatstone's Bridge for Comparing the Capacities of two Condensers." By Prof. S. P. THOMPSON.

"On a Simple Form of Insulating Stand." By Prof. S. P. THOMPSON.

"On an Illustration of certain Electrostatic Phenomena by means of Mayer's Floating Magnets." By Prof. S. P. THOMPSON.

"On Experiments illustrating Attraction and Repulsion. By J. MONCKMAN.

"On an Integrating Anemometer." By WALTER BAILY.

January 26th, 1884.

Prof. CLIFTON, President, in the Chair.

Special General Meeting.

Resolutions were passed to make certain alterations in the Articles of Association of the Society, which would give to Articles 36, 39, and 48 the following form:—

ART. 36. "The affairs of the Society shall be managed by a

Council consisting of a President, Permanent Vice-Presidents, not more than four nor less than two other Vice-Presidents, two Secretaries, a Treasurer, a Demonstrator, and not more than ten other persons, all of whom must be Ordinary Members of the Society."

ART. 39. "At each Annual General Meeting all Members of the Council, except the Permanent Vice-Presidents, shall retire from Office, and the Society shall elect a New Council in manner herein provided."

ART. 48. "Every Member of the Society who has filled the Office of President shall be a Permanent Vice-President."

Ordinary Meeting.

The following was elected a Member of the Society:—

FUNG YEE.

The following communications were made:—

"On the Construction and Adjustment of Direct Reading Electric Measuring Instruments." By Profs. W. E. AYRTON and J. PERRY.

"On the Determination of Chemical Affinity in terms of Electromotive Force.—Part VIII. On the E.M.F. set up during Interdiffusion." By Dr. C. R. ALDER WRIGHT and C. SIMPSON.

Annual General Meeting.

February 9th, 1884.

Prof. CLIFTON, President, in the Chair.

The Resolutions passed at the Special Meeting on January the 26th were confirmed.

The following Report of the Council was read by the President:—

The Session of the Society which has just been completed, though not marked by the communication of any great discovery, has been full of steady work. The Meetings have been well attended, and the papers and discussions have fully occupied the time at our disposal. Several interesting communications on lenses have been made by the President, of which the Council hope before long to be

furnished with the MSS., so that these communications may be published in the 'Proceedings.' The beautiful optical effects produced by Mica Films, prepared by Mr. Lewis Wright, and the striking experiments on Magnets, shown by Prof. Hughes, will be vividly remembered. A careful series of measurements on the Velocity of Sound in Air has been made by Mr. Blaikley; and the important subjects of Colour-sensations and Colour-blindness have been brought before the Society by Mr. Droop.

In the report of 1883 it was mentioned that the Council had arranged that all Members who desired notices of the titles of papers to be read at our Meetings should receive them gratuitously on application to Messrs. Taylor and Francis. During the past Session these notices have been sent two or three days before each Meeting to about seventy Members, and it has been possible by this means to announce communications of which the Secretaries have received notice too late for announcement in the weekly papers.

The Council have for some time felt the difficulty of retaining the services of those who have held the important office of President, and at the same time of recommending at each election a sufficient number of new Members of Council. In order to remove this difficulty the Council have proposed, and the Society has made, a change in the Articles of Association, which will give to all past Presidents the position of permanent Vice-Presidents. This is a rule in some other societies, and the Council believe that its adoption will be found advantageous.

The Library has been rearranged. Volumes and numbers required to complete sets have been obtained, either by purchase or gifts. The publications requiring it have been prepared for binding. The whole has been catalogued, and consists of

	Volumes.
Separate Works	480
Transactions of Societies, Proceedings, and Periodicals	200
Separate memoirs	88
	768

The Library has been enriched by several donations, the principal of which is a recent and most acceptable gift, by Lady Siemens, of 119 volumes, forming part of the library of her late husband, whose lamented death has deprived this Society of one of its most honoured members. The Society is also indebted to Dr. Guthrie for gifts of many valuable works.

The printing of the first volume of Joule's works is now finished, and the sheets are ready for the binders. A specimen-copy has been bound for inspection, and the volume will shortly be in the hands of Members. The ready access to these important papers will be a valuable aid to the prosecution of Physical Research. Some progress has been made in the translation of Volta's works, but the death of the gentleman to whom the work was entrusted has caused an interruption, and fresh arrangements will have to be made by the Council.

The Council would again call attention to the obligation under which the Society rests to the Lords of the Committee of Council on Education for the use of the Physical Lecture-room and Laboratories, so generously placed at their disposal.

The Society has to deplore the loss by death of an unusually large number of its Members, including several of the foremost men of science. The last annual report was read immediately after the death of Henry John Stephen Smith. In this report we have to record the deaths of the President of the Royal Society, of Sir William Siemens, of M. Plateau, of Mr. Cromwell Fleetwood Varley, of Lieut. Hastings R. Lees, and of Mr. C. Merrifield.

William Spottiswoode, descended from an old Scotch family which has produced many distinguished members, was born in London on January 11, 1825. He entered Balliol College, Oxford, in 1842, took a first-class in Mathematics in 1845, and obtained the Junior, and afterwards the Senior Mathematical Scholarships. He is described as having already an extraordinary liking for, and great skill in, the Morphology of Mathematics. Upon leaving Oxford he entered into the business of the Queen's Printers, which was resigned to him by his father. He continued in that business throughout his life, and it was largely developed under his care. He was elected a Fellow of the Royal Society in 1853, and held the office of Treasurer from 1871 to 1878. In 1879 he became President, and held that office until his death. He was President of the British Association in 1878, and of the London Mathematical Society from 1870 to 1872. He was admitted a Member of this Society in its first Session in 1874. He received the degree of LL.D. at Cambridge, Dublin, and Edinburgh, and that of D.C.L. at Oxford. Mr. Spottiswoode's greatest distinction was earned in the region of Pure Mathematics, and his numerous and important papers were specially characterized by elegance and symmetry. Up to the year of 1871 his communi-

cations to science appear to have been almost entirely confined to Mathematics; but about that time he began to devote his attention more to Physics, and he was naturally attracted to that branch of Physics in which the elegance and symmetry he delighted in are most conspicuously shown. In 1871 he published in the 'Philosophical Magazine' a paper "On some Experiments on Successive Polarization made by Sir C. Wheatstone." This was followed in 1872 by a paper in the 'Proceedings' of the Royal Society, "On the Rings produced by Crystals when submitted to circularly Polarized Light," and by a paper in 1874, "On Combinations of Colour by Polarized Light" (also communicated to this Society). In 1875 a communication "On a revolving Polariscope" was made to the Royal Institution and to this Society. The other Physical subject to which his attention was specially given was the Electric Discharge *in vacuo*. In this investigation he spared no expense in apparatus, and his well-known induction-coil is the largest which has been made. His papers on this subject, published in the 'Proceedings' of the Royal Society, are:—1874–75, "On Stratified Discharges through Rarefied Gases;" 1876–77, "Observations with a Revolving Mirror," and "On a rapid Contact-breaker, and the Phenomena of the Flow" (also communicated to this Society); 1877, "On Stratified and Unstratified forms of the Jar-Discharge," and "Photographic Image of the Stratified Discharge;" 1878, "Discharge from a Condenser of large Capacity;" 1879, "On the Sensitive State of Electrical Discharges through Rarefied Gases" (also communicated to this Society); 1879–80, "On some of the Effects produced by an Induction-Coil with a de Meritens Magneto-electric Machine," and "On the Sensitive State;" 1881, "On Shadows of Striæ and Multiple Radiations from Negative Terminal," and "On the Movement of Gas in Vacuum Discharges." Several of the latter papers were prepared in combination with Mr. J. F. Moulton. As President of the Royal Society Mr. Spottiswoode was able to bring great capacity for business, unerring tact, and wide-spread sympathy to promote the advancement of science. He died of typhoid fever on June 27, 1883. The high estimation in which he was held, and the deep regret felt for his loss, are shown in the very general request that he should be buried in Westminster Abbey, where he now lies, among those great men whom England desires to hold in special remembrance.

Charles William Siemens was born at Leuthe, in Hanover, on

April 4, 1823. In 1843 he came to England to introduce a new method of electro-gilding, invented by himself and his brother Werner, and was enabled by the help of Mr. Elkington to bring it into practical use. The next year he returned to England with his Chronometric Governor, a modification of which is now in use in the Greenwich Observatory for regulating the motion of instruments. In 1850 he received from the Society of Arts its Gold Medal for his Regenerative Condenser. In 1853 he read, before the Society of Civil Engineers, a paper "On the Conversion of Heat into Mechanical Effect," for which he received the Telford Premium and the Medal of the Institution. In 1857, in conjunction with his brother Frederick, he brought out what was probably his greatest invention, the Regenerative Gas-Furnace, in which the heated products of combustion are made, on leaving the furnace, to give up their heat to the gas and air which are entering. The very high temperature obtained in such a furnace enabled Mr. Siemens to develop a new method of manufacturing steel, which has been so successful that steel made by his method is largely used in the manufacture of boilers and hulls of ships. In 1867 the principle underlying all the dynamo machines was communicated by him to the Royal Society in a paper, "On the Conversion of Dynamical into Electrical Force without the aid of Permanent Magnetism." The invention was due to Werner Siemens; but it had also occurred to Sir Charles Wheatstone, and was announced by him to the Royal Society in a paper read by him on the same evening as that on which Mr. Siemens's paper was read. The firm of Siemens Brothers has been largely employed in the construction of submarine cables, and more recently in that of electrical machines. The Portrush and Bushmill Electric Tramway, completed only two months before his death, forms one of Dr. Siemens's greatest achievements. He made some experiments on the growth of plants under the electric light, and took a great interest in the construction of arrangements for the consumption of smoke. He was made a D.C.L. of Oxford in 1870, and was knighted in March last, besides receiving many other honours. He was elected a Fellow of the Royal Society in 1862, and served on the Council in 1869 and 1870. He was admitted a Member of this Society in its first Session in 1874. Sir William Siemens combined great amiability of character with resistless energy, and clear knowledge of scientific principles with boundless futility of invention. He has been preeminent in the application of science to the wants of life; and his loss must needs make our progress in this

application slower than it might otherwise have been. He died on November 19, 1883.

Lieut. Hastings R. Lees was born on January 4, 1853. He entered the Navy as Naval Cadet on the 'Britannia' in 1866, and attained the rank of Lieutenant in 1875. After passing through the usual courses of study at Greenwich and Portsmouth in order to qualify for a Gunnery-Lieutenant, he was appointed to the 'Swiftsure' flagship in the Pacific. In October last, when on shore at Vancouver Island, he was thrown from a carriage and died from the injuries he then received.

Lieut. Lees was a promising officer, and keenly interested in all scientific matters connected with his profession. He became a Member of this Society in March 1879.

Cromwell Fleetwood Varley was born in the year 1828, and in 1846 he entered the service of the then infant Electric Telegraph Company. He not only had had a good scientific training, but he was well versed in the use of tools; and having a remarkable aptitude for the application of scientific knowledge to practical purposes, he soon made himself a valuable and useful officer. He remained in the service of the Telegraph Company until 1866, having attained the highest office open to him, and having very materially improved the working of their system. From that date he became associated with Atlantic-Cable enterprises, and, in conjunction with Sir William Thomson and Professor Fleeming Jenkin, he solved the difficult problem of long-cable working. His career was connected entirely with telegraphy. He took out no less than thirty-three patents. He introduced accurate measurement in testing lines and localizing faults; but his principal invention was the application of condensers to expedite the working of long submarine cables. The specifications of his numerous patents contain a mass of original observations that anticipated much later work; and he had a remarkable skill in applying the crude ideas of others and seizing upon their practical bearing. As an experimental electrician he was unrivalled, and his skill was remarkably shown in localizing faults at the bottom of the ocean.

Among the more important of Mr. Varley's purely scientific papers may be mentioned two papers in the 'Proceedings' and 'Transactions' of the Royal Society. One of these was a remarkable investigation into the nature of the electric discharge in rarefied

gases, in which he proved that appreciable mechanical force was exerted upon surfaces exposed to the discharge, a fact since more fully investigated by Mr. Crookes. The second related to the influence of electrification on the capillary properties of a surface of mercury in contact with diluted sulphuric acid, a subject to which the subsequent researches of Mons. G. Lippmann have attracted a considerable amount of attention. He died on the 2nd of September last.

Joseph Antoine Ferdinand Plateau was born at Brussels on the 14th of October, 1801. He studied Mathematics and Physics, after leaving school, at the University of Liége, where he received the degree of Doctor in 1829. His inaugural thesis, "On some Properties of the Impressions produced by Light on the Organ of Vision," raised him to a high rank among men of science. In 1834 he presented to the Royal Academy of Belgium his memorable work entitled 'Essay on a General Theory embracing all the Visual Appearances which succeed the Contemplation of Coloured Objects &c.' In 1835 Plateau was nominated Professor of Physics at the University of Ghent. As a teacher and as an investigator his work was characterized by the ingenuity with which he conceived and arranged his experiments, multiplied and varied them to an infinite extent, employing the most simple and ordinary means, such as are within the reach of every one.

In 1829, at the very outset of his scientific career, wishing to observe the consecutive effects of a strong excitation of the retina, Plateau, carried away by his passion for science, committed the fatal imprudence of fixing his eyes for nearly twenty seconds on the solar disk in its full brightness. This experiment gives us an idea of the energy and devotion with which Plateau pursued his studies. Unhappily it entailed upon him the most disastrous consequences: he remained blind for several days; his sight returned, but his eyes had received permanent injury, and his sight gradually became weaker, until, in 1843, fourteen years after his fatal experiment, it was entirely extinguished. This loss, irreparable as it was, could not check the scientific ardour of Plateau.

He was, before everything, an experimenter, and his principal instrument of research having failed him, he was determined to see through the eyes of others. As his experiments extended into several distinct domains of science, it was necessary for him to borrow the eyes of a great many different persons.

Plateau had been the pioneer in a special domain of physiological

optics; blind, he created a branch of experimental physics. In 1842 appeared, in the 'Bulletin' of the Royal Academy of Belgium, his work "On the Phenomena presented by a Mass of Free Liquid removed from the Action of Gravity." The experiments in question, characterized by beauty and ingenuity, were realized, as were most of his experiments, with the simplest possible appliances. This work was the starting-point of a long series of researches, not less remarkable, on Molecular Forces, published between 1849 and 1868 under the title "Experimental and Theoretical Researches on the Figures of Equilibrium of a Mass of Liquid without Weight." In 1873 these papers were collected and published in two volumes, with the title 'Statique expérimentale et theorique des liquides soumis aux seules forces moléculaires.'

An activity so considerable in other fields of science did not, however, prevent him from pursuing the subject of his early labours and his first triumphs. His blindness naturally arrested his researches on physiological optics. The arrest, however, was but momentary: having drilled his helpers to this kind of investigation, he continued his studies, defended by the aid of new experiments the ideas which he had previously propounded, and, blind as he was, arrived at new and important results on luminous and coloured sensations. In 1872 he published the work "On the Measure of Physical Sensations," in which he controverted the views of E. H. Weber and Fechner. In 1878 he communicated to the Royal Academy of Science of Belgium a paper, "On a Law of Persistence of Impressions in the Eye," a work too little known, in which he completes and rectifies one of the propositions formulated fifty years before. From 1877 to the time of his death, which occurred on September 15, 1883, Plateau was engaged in compiling a valuable catalogue of all the papers he could meet with which bore on his special optical inquiries.

Plateau was a Commander of the Order of Leopold, Member of the Royal Academy of Belgium, Correspondent of the Institute of France, Member of the Academy of Sciences of Berlin, the Royal Academy of Sciences of Amsterdam, and the Royal Society of London. He was elected an Hon. Member of the Physical Society on February 8, 1879.

Charles Watkins Merrifield was born at Brighton in 1828. He received an appointment in the Education Department in 1847, and was soon promoted to the office of Examiner. In 1867 he was appointed Principal of the Royal School of Naval Architecture and Marine Engineering at South Kensington; but on the transfer of

this department to Greenwich he resumed his office as Examiner in the Education Department. He was for many years Honorary Secretary of the Royal Institute of Naval Architecture. He was elected a Fellow of the Royal Society in 1863. He was President of the Section of Mechanical Science at the British-Association Meeting in 1869. He had also held the office of President of the London Mathematical Society, and was one of the original Members of the Physical Society. His contributions to Mathematics were very numerous, and he wrote some important papers on sea-waves. For some years he frequently sat as Scientific Assessor in the Wreck-Court; he also served on several Royal Commissions. He died on the 1st of January last.

The Treasurer made the Financial Statement given below.

The Society then proceeded to the election of Officers and other Members of Council for the ensuing year. The Council was constituted as follows:—

President.—Prof. F. Guthrie, Ph.D., F.R.S.

Permanent Vice-Presidents.—Prof. W. G. Adams, M.A., F.R.S.; Prof. R. B. Clifton, M.A., F.R.S.; Prof. G. C. Foster, F.R.S.; Dr. J. H. Gladstone, F.R.S.; Sir William Thomson, LL.D., F.R.S.

Other Vice-Presidents.—Prof. W.E. Ayrton, F.R.S.; J. Hopkinson, M.A., D.Sc., F.R.S.; Lord Rayleigh, M.A., F.R.S.; Prof. W. Chandler Roberts, F.R.S.

Secretaries.—Prof. A. W. Reinold, M.A., F.R.S.; Walter Baily, M.A.

Treasurer.—Dr. E. Atkinson.

Demonstrator.—Prof. F. Guthrie, Ph.D., F.R.S.

Other Members of Council.—Shelford Bidwell, M.A., LL.B.; Conrad W. Cooke; Prof. F. Fuller, M.A.; R. T. Glazebrook, M.A., F.R.S.; R. J. Lecky, F.R.A.S.; Prof. O. J. Lodge, D.Sc.; Prof. H. McLeod, F.R.S.; Hugo Müller, Ph.D., F.R.S.; Prof. J. Perry, M.E.; Prof. S. P. Thompson, D.Sc.

The following was elected an Honorary Member:—

Prof. H. A. Rowland.

Votes of thanks were passed to the Lords of the Committee of Council on Education; to the President; and other Officers of the Society; and to the Auditors.

THE TREASURER IN ACCOUNT WITH THE PHYSICAL SOCIETY, FROM JANUARY 1ST, 1882, TO DECEMBER 31ST, 1883.

Dr.	£ s. d.	£ s. d.
Balance in Bank		138 0 9
" hands of Treasurer		51 10 8
7 Entrance-Fees	7 0 0	
Subscriptions for 1880	3 0 0	
" 1881	7 0 0	
" 1882	18 0 0	
" 1883	115 0 0	
" 1884	3 0 0	
Life Composition	40 0 0	
		193 0 0
One year's Dividend on £400 Furness 4 per cent. Debenture Stock, less Income Tax	15 11 4	
One year's Dividend on £460 5 per cent. Midland Preference Stock, less Income Tax	22 7 6	
One year's Dividend on £200 3½ per cent. Metropolitan Board of Works Stock, less Income Tax	6 16 10	
One year's Dividend on £200 Lancaster Corporation Stock	7 16 2	
		52 11 10
Sales, less Commission		8 5 9
		£443 9 0

Cr.	£ s. d.	£ s. d.
Taylor and Francis:—		
Reprint of Joule's Scientific Papers	250 0 0	
Proceedings, vol. v. (parts 3 & 4)	62 1 6	
Postage and addressing	6 8 0	
Members' separate copies	13 0 6	
Miscellaneous printing	13 0 11	
		344 10 11
Reports of Meetings		10 0 0
Williams and Norgate:—Periodicals		9 8 0
Chapman:—Attendance and Petty Cash		4 6 11
Stationery and Printing		3 6 0
Petty Cash:—		
Mr. Reinold	1 14 2	
Mr. Baily	0 15 0	
Mr. Atkinson	1 14 0	
		4 3 2
Balance in Bank		62 8 0
" hands of Treasurer		5 6 0
		£443 9 0

Audited and found correct,

E. W. JONES,
F. W. BAYLY, } *Auditors.*

London, February 1st, 1884.

PROPERTY ACCOUNT OF THE PHYSICAL SOCIETY.

Assets.	£	s.	d.	Liabilities.	£	s.	d
Balance in Bank	62	8	0	Subscriptions in advance, for 1884	3	0	0
" hands of Treasurer	5	6	0				
Estimated Subscriptions due	35	0	0				
£400 Furness 4 per cent. Debenture Stock	412	0	0				
£460 Midland 5 per cent. Preference Stock	565	0	0	Balance	1510	14	
£200 Metropolitan Stock	210	0	0				
£214 Lancaster Corporation Stock	214	0	0				
	£1513	14	0		£1513	14	0

We have examined the above Account, and also the Securities at the Bank, and find the same to be correct.

London, February 1st, 1884.

E. W. JONES,
F. W. BAYLY, } *Auditors.*

The following works have been presented to the Society:—

Carpenter, W. L. Energy in Nature.	The Author.
Du Bois-Raymond. Thierische Electricität. 2 vols.	Lady Siemens.
Dühring. Critische Geschichte der Mechanik.	"
Eisenlohr. Lehrbuch der Physik.	"
Gregory, G. Economy of Nature. 3 vols.	"
Kirchhoff. Gesammelte Abhandlung.	"
Loan Collection of Scientific Apparatus, 1876. Catalogue.	Dr. Guthrie.
Marbach. Physikalisches Lexikon. 6 vols.	Lady Siemens.
Mascart and Joubert (Atkinson). Electricity and Magnetism.	Dr. Atkinson.
Müller. Fortschritte der Physik.	Lady Siemens.
Regnault. Cours de Chemie. 4 vols.	"
Reuliaux. Der Constructeur.	"
Saunier. Treatise on Horology. 2 vols.	E. Rigg, Esq.
——. Watchmaker's Handbook.	"
Stanley. On Fluids.	The Author.
Technological Dictionary. Eng., Fr., & Ger. 3 vols.	Lady Siemens.
University College, London. Catalogue of Library. 3 vols.	The College.

The following are the principal Periodicals which have been presented to the Society:—

Great Britain and Ireland.

Royal Society. Proceedings, 29 vols.	Dr. Guthrie.
—— ——. Phil. Trans. 27 vols.	"
—— ——. Phil. Trans. Abridged by Hutton. 18 vols.	"
—— ——. Catalogue of Scientific Papers. 8 vols.	"
Royal Dublin Society. Transactions.	The Society.
Royal Institution. Proceedings. 5 vols.	Lady Siemens.
—— ——. Proceedings. 4 vols.	The Society.
Chemical Society. Journal. 20 vols.	Lady Siemens.
—— ——. ——. 13 vols.	Dr. Guthrie.
Physical Society. Proceedings. 2 vols.	Lady Siemens.
Society of Arts. Journal.	The Society.
Institute of Mechanical Engineers. Proceedings.	The Institute.
Society of Telegraph Eng. and Electricians. Journal.	The Society.
Cambridge Phil. Society. Proceedings. 4 vols.	The Society.
Society of Philosophical Experiments and Conversations. Minutes.	L. Clarke, Esq.
Philosophical Magazine. 44 vols.	Lady Siemens.
The Inventors' Record. 7 vols.	"
Stonyhurst College. Observations.	Prof. Perry.

Scientific Roll.	The Editor.
Kew Committee. Report.	The Committee.
Radcliffe Library, Oxford. Catalogue of Additions.	The Library.
University College, London. Calendar.	The College.
Glasgow University Calendar.	The University.

America.

The Smithsonian Institution. Report.	The Institution.
Johns Hopkins University Circulars. 12 Nos.	The University.
American Philosophical Society. Proceedings, 5 vols.	Lady Siemens.

France.

Société Française de Physique. Ordres du jour.	The Society.
—— —— ——. Séances.	"
Bureau des Longitudes. Annuaire.	The Bureau.
Les Mondes. 23 vols.	Lady Siemens.

Germany.

Repertorium für Experimental Physik. 21 vols.	Lady Siemens.
Jahresberichte Fortschritte der Chemie. 3 vols.	"
—— —— der Physik. 30 vols.	"
Centralblatt Chemisches. 31 vols.	Dr. Guthrie.
Gmelin. Handbook of Chemistry. 8 vols.	Lady Siemens.

Japan.

Science Department, Tokio. Memoirs.	The Department.
Seismological Society of Japan. Proceedings.	The Society.

Norway.

Norwegian North-Atlantic Expedition. 3 vols.	The Committee.

Russia.

St. Petersburg Journal of Chemistry and Physics.	The Editors.

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